BAILLIÈRE'S

ENCYCLOPÆDIA OF SCIENTIFIC AGRICULTURE

BAILLIÈRE'S ENCYCLOPÆDIA OF SCIENTIFIC AGRICULTURE

EDITED BY

HERBERT HUNTER, D.Sc.,

SCHOOL OF AGRICULTURE, CAMBRIDGE.

IN TWO VOLUMES

VOL. I. A—L

LONDON:

BAILLIÈRE, TINDALL AND COX,

7 AND 8 HENRIETTA STREET, COVENT GARDEN, W.C. 2

1931

PRINTED IN GREAT BRITAIN

PREFACE.

The improvements made in agriculture up to the beginning of the nineteenth century were due almost entirely to isolated, individual efforts. Spasmodic and unquestionably empirical as many of these efforts were, they nevertheless contributed largely to the formation of a standard of agricultural practice which was admittedly high. But changes throughout the world generally during the last hundred years have imposed upon the agriculturist the necessity for still greater efficiency in production; and, indeed, in many cases demand the adoption of methods wholly unattainable by the means that were formerly considered adequate.

Scientific agriculture in this country may be said to have received its initial stimulus from the work of Lawes and Gilbert at Rothamsted, and of Voelcker at Woburn. The practical value of these pioneer efforts and the wide interest they aroused led gradually to more extended efforts in agricultural investigations, and at the same time promoted a deeper interest in agricultural education. Since the War, developments more particularly in research have been accelerated, and there are now in operation comprehensive organizations for agricultural research, largely supported by State funds. By these agencies many of the problems confronting the farmer have been brought under review in a systematic manner, and already substantial progress has been made in assimilating into practice the results so obtained.

The object of this Encyclopædia is to present the various branches of agriculture in the new aspect they are gradually assuming under the influence of scientific enquiry, and to outline the changes in former practice rendered possible and necessary in the light of new knowledge. It consists of a number of leading articles, and of descriptive matter which has been included to assist in the proper interpretation of technical matters.

The ordinary operations and equipment of agriculture, which are comprehended in the term "husbandry," have been adequately described in works published previously, and, except where for special reasons it has been found necessary to supplement this information, the reader's acquaintance with it is assumed. Thus, the Encyclopædia may justly claim to be an entirely new exposition.

The main articles have been contributed by recognized authorities in this country and abroad, and embody in a concise form a survey of the present-day position. But whilst envisaging the advances which may justly be attributed to scientific investigation, they also aim at bringing into its proper relation to practice the rapidly increasing mass of valuable information contained in scientific journals and pamphlets, not always readily accessible to the layman.

Throughout, an effort has been made to state in a readily intelligible manner the underlying principles on which the various lines of enquiry are based. Consequently, although the subject-matter is largely concerned with British agriculture, it is applicable in its broad outlines to Canada,

New Zealand, Australia, and large areas of the United States of America and other countries characterized by a temperate climate.

The requirements of both the student and of the farmer have been visualized in the preparation of this work. Thus, for the former, in addition to an appreciation of the existing position, the outlines of various problems are drawn, the progress towards their solution described, and the possible lines and objectives of further investigations indicated. The whole is supplemented by abundant references to scientific publications wherever necessary, so that the details of the various investigations upon which conclusions are based may be consulted without difficulty. For the farmer, attention is directed to such results as will legitimately justify changes or modification of former practice. But it will be well to reiterate what has so often been expressed, that in practice agriculture is an art rather than a science, and new methods, regardless of the extent to which they may have been verified experimentally, will prove successful in practice only when they receive skilful adjustment to the varying circumstances which ever surround the life of plants and animals.

The separate units of the Empire are mutually dependent, and the formulation of schemes of future development for one must be considered in relation to the possible repercussion on the others. For this reason a survey of the agriculture of each of the different countries is included, together with a brief account of the lines which developments may be expected to follow in the future. It is hoped that for students of agriculture in its widest aspect, and for those who desire a bird's-eye view of the changes arising out of the application of scientific methods of enquiry to agricultural problems, this survey will prove particularly valuable.

Regarding the illustrations, of which there are twenty-nine plates and numerous line drawings: the selection of these has been made to conform with the aims of the Encyclopædia; many, consequently, interpret aspects not exemplified previously, and it is hoped they will not only assist in interpreting the articles in which they appear, but will add to the value of the Encyclopædia as a whole.

On behalf of the publishers and myself I gladly take this opportunity of expressing to the contributors our thanks for the ready and generous assistance they have afforded us; any benefit this work may confer on those immediately concerned in the development of agriculture is very materially the result of their efforts.

As Editor, I am greatly indebted to many friends for advice and helpful criticism; this applies in especial measure to Dr. T. Deighton, who, in addition to contributing several articles, has prepared most of the purely descriptive matter.

In conclusion, it only remains for me to state that the whole credit for the inception of the ideas underlying the Encyclopædia belongs to the Publishers. The general scheme of presentation was outlined by the late Mr. A. B. Bruce, M.A., on whose sudden and widely regretted decease I was requested to complete the work he had so well begun.

HERBERT HUNTER.

School of Agriculture,
Cambridge
August, 1931.

INTRODUCTION.

As indicated in the Preface, the underlying idea of this Encyclopædia is the presentation of the results of scientific investigation in their application to the practice of agriculture. With this object in view the main articles dealing with different branches of agriculture have been regarded as a basis around which others dealing with particularized features of research have been disposed. The whole is arranged in alphabetical form, with ample cross references linking various relevant subjects, and at the same time facilitating the finding of subjects which may be grouped under one heading.

Although an effort has been made to include at least some phase of all branches of agriculture, the space allocated to each subject has been decided rather by the extent to which it has been the object of research than by its relative economic importance.

The subject of the soil is treated at considerable length in regard to established systems of farming, and the requirements of various crops deduced from their existing geographical distribution. Other aspects of more specialized interest which have formed the subjects of investigations are nitrification, loss by drainage waters, liming and soil colloids and humus; these appear as separate articles, but their inter-relationship is indicated by cross references.

The ordinary arable and pasture crops, which in most essentials exhibit features common to all countries with a temperate climate, are dealt with at considerable length; the results of extended efforts by various bodies to determine the most remunerative varieties to cultivate, the principles of manuring, and the best manurial treatment, are brought under review, followed by a suitable commentary on the modifications of agricultural operations that have been found beneficial in the case of each crop. A general outline of the manner of the commercial utilization of certain crops is added, thereby bringing the underlying aims of plant breeding in their relation to these crops into proper perspective. The articles on crops are completed by a general description of the common diseases and insect pests to which they are subject, together with the means usually employed in combating them.

The improvements in crop plants resulting from breeding rely for their maintenance on the continual propagation and circulation of pure stocks of seed. But there are other and very important conditions which may affect the productivity of seed, some attributable to causes in operation whilst it still forms part of the mother plant, and others originating in the conditions of treatment subsequent to harvest. Then there remain the questions of plant diseases, more particularly in relation to their transmission by the seed, and of the value of fungicides as a means of control; all these features exert an influence on the ultimate yield of crops, and are consequently dealt with at length. Finally, the

increasingly important problems attending the resistance of plants to disease and to insect pests are outlined in several articles.

The interest of the student is frequently extended to include such tropical crops as rice, cotton, bananas, etc., and for his benefit short articles on such crop plants are included. In their preparation particular emphasis has been laid upon problems of crop improvement in each case.

The problems attending the production of improved plants are manifold, as will be readily realized from the articles on the different crops. The underlying causes limiting more rapid development in this direction are obscure, and will require long and sustained efforts to unravel them. The articles on Mendelism and cytology indicate the lines on which the geneticist is assisting in the general problem.

Articles on breeding forage plants and grasses suffice to indicate the complexity of the general problem, and in these cases, of the technique of actual breeding, whilst an article on vegetable breeding outlines the extraordinary possibilities of improvement in this direction.

A great deal of attention has been directed to questions attending the technique of yield testing in recent years, and the article on this subject presents the different methods now under survey in a closely reasoned but readily applied manner.

The recent large and significant developments in fruit growing, market gardening, and the cultivation of glasshouse crops form the subjects of extended expositions. Here, as in the case of field crops, the cultural and commercial conditions that determine the most desirable varieties to cultivate are discussed in detail concurrently with manuring. The crops appearing under these headings bear with them the ever-present problems of disease and insect pest control, and special efforts have been made to indicate the results of recent research in these matters in their relation to horticultural practice.

In the past few years the storage of fruits and vegetables and of agricultural products at low temperatures, and more recently still the preservation of fruits and vegetables by canning, are being practised on an increasingly large scale. A comprehensive article on refrigeration is accordingly included, also one on the preservation of fruit and vegetables, with special reference to the most suitable varieties to cultivate for disposal to canneries, as far as this is at present ascertained.

It will be noticed that there is no account of the breeds of livestock or livestock as such. This subject has already an ample and up-to-date literature, and poultry, which have become such an important, world-wide feature in agriculture in the last ten years, are the only livestock here receiving detailed consideration.

Moreover, the elucidation of problems of nutrition undoubtedly mark the line of greatest progress in matters relevant to livestock in recent times, and the scientific basis of foods and feeding consequently receives adequate treatment. Accounts of the various feeding stuffs, together with the scientific principles which must dictate the proper method and extent of their utilization, are included also, whilst for the student and scientific worker the method of determining feeding values experimentally is explained in detail.

In spite of the application of scientific methods to agricultural problems, the individual farmer, and consequently the community, may fail to

secure the full advantages of improvements through faulty organization in farming systems, or through defects in the manner of disposing of farm produce. This aspect of agriculture has come under survey in recent years, and as a result the value of the analytical method of determining the costs of production has been securely established.

Included in the text, in their appropriate alphabetical position, there are numerous definitions of chemical and other terms. Unless he is constantly in touch with a subject, there must be many occasions on which the reader wishes to refresh his memory on some point referred to in individual articles, and the purpose of these definitions is to afford him a ready means to this end.

No attempt has been made to describe agricultural machinery as a whole, for this branch, like livestock, has already an up-to-date and comprehensive literature of its own. A few features which lend themselves to a description applicable as a general principle, however, have been included on this account.

Based on the results of scientific enquiry, there are various legal enactments in force to-day with which agriculturists must necessarily make themselves conversant. Limitations of space preclude the inclusion of all these, but it is hoped that the selection made will be found of assistance to a wide circle of readers.

It is impossible in a short account such as this to enumerate all the topics included in the following pages, but it will be noticed that the comprehensive list includes articles on some lines of enquiry that are only gradually receiving adequate attention from scientific workers. Such, for example, is meteorology, which is a fundamental factor in determining the geographical distribution of crops, whilst the influence of the weather on the incidence of plant diseases and insect pests is especially important.

Amongst other articles of this category only one need be mentioned now, namely, winter hardiness and drought resistance in plants. This article, indeed, provides a most interesting summary of the many physiological and chemical questions involved in the consideration of these highly interesting properties in plants—properties of considerable economic importance even in countries with a temperate climate.

In conclusion, it is hoped that this Encyclopædia will prove of both interest and practical value to all concerned with agriculture. No effort has been spared to make it a comprehensive and ready work of reference, but doubtless, sins of omission or commission will make themselves apparent to the reader, and notes of printer's or other errors, and particularly suggestions for the improvement of future editions, will be greatly welcomed by the Editor.

H. H.

LIST OF PLATES

CONTRIBUTORS.

The letters given on the right-hand side are the initials with which the articles are signed.

Amos, A., M.A., Wye, Kent.	A. A.
Armstrong, S. F., M.A., National Institute of Agricultural Botany, Cambridge.	S. F. A.
Barker, Professor Aldred F., M.Sc., M.T.I., Professor of Textile Industries, The University, Leeds.	A. F. B.
Bartlett, S., M.C., B.Sc., N.D.D., National Institute for Research in Dairying, Reading.	S. B.
Bennett, F. T., B.Sc. (Agric.) Ph.D. (Lond.), Armstrong College, Newcastle-on-Tyne.	F. T. B.
Bewley, W. F., D.Sc., Director, Experimental and Research Station, Cheshunt, Herts.	W. F. B.
Bond, J. R., M.B.E., M.Sc., County Agricultural Organizer, Derby.	J. R. B.
Boyes, D., M.A., Director, Horticultural Research Station, School of Agriculture, Cambridge.	D. B.
Brennan, A. T., Assistant Trade Commissioner, Office of the High Commissioner for South Africa, London.	A. T. B.
Brierley, W. B., D.Sc., Head of Department of Mycology, Rothamsted Experimental Station, Harpenden.	W. B. B.
Burgess, A. H., B.Sc. (Agric.), South-Eastern Agricultural College, Wye, Kent.	A. H. B.
Comber, Professor N. M., D.Sc., F.I.C., The University, Leeds.	N. M. C.
Conacher, H. M., Assistant Secretary, Department of Agriculture for Scotland, Edinburgh.	H. M. C.
Cunliffe, N., M.A., D.Sc., School of Rural Economy, Oxford.	N. C.
Dale, H. E., C.B., M.A., Principal Assistant Secretary, Ministry of Agriculture and Fisheries, London.	H. E. D.
Deighton, T., M.A., Ph.D., B.Sc., Animal Nutrition Institute, School of Agriculture, Cambridge.	T. D.
Dobson, A. T. A., C.B.E., B.A., Assistant Secretary, Ministry of Agriculture and Fisheries, London.	A. T. A. D.
Duly, S. J., M.A., City of London College, Moorfields, London.	S. J. D.
Fisher, E. A., M.A., B.Sc., D.Sc., F.I.C., F.Inst.P., Director of Research, Research Association of British Flour Millers, St. Albans, Herts.	E. A. F.
Foreman, F. W., M.A., F.I.C., Animal Nutrition Institute, School of Agriculture, Cambridge.	F. W. F.
Fryer, J. C. F., O.B.E., M.A., Director and Entomologist, Plant Pathological Laboratory, Ministry of Agriculture, Harpenden.	J. C. F. F.
Garner, F. H., M.A., School of Agriculture, Cambridge.	F. H. G.

Garner, H. V., M.A., Rothamsted Experimental Station, Harpenden. H. V. G.

Gimingham, C. T., B.Sc., F.I.C., Plant Pathological Laboratory, Ministry of Agriculture and Fisheries, Harpenden. C. T. G.

Golding, Captain J., D.S.O., F.I.C., National Institute for Research in Dairying, Reading. J. G.

Goode, C. W., N.D.A., The University, Leeds. C. W. G.

Grisdale, Hon. J. H., D.Sc.A., B.Agr., Deputy Minister of Agriculture for Canada, Ottawa. J. H. G.

Halnan, E. T., M.A., Animal Nutrition Institute, School of Agriculture, Cambridge. E. T. H.

Hendrick, Professor James, B.Sc., F.I.C., North of Scotland College of Agriculture, Aberdeen. J. H.

Hinchcliff, J. H., Ph.D., Agricultural Director, Department of Agriculture, Dublin. J. H. H.

Hunter, H., D.Sc., Plant Breeding Institute, School of Agriculture, Cambridge. H. H.

Huskins, C. L., B.S.A., M.Sc., Ph.D., Professor of Genetics, McGill University, Montreal. C. L. H.

Imms, A. D., M.A., D.Sc., Chief Entomologist, Rothamsted Experimental Station, Harpenden. A. D. I.

Jenkin, T. J., M.Sc., Welsh Plant Breeding Station, Aberystwyth. T. J. J.

King, J. S., Ph.D., B.Sc., (Econ.), B.Sc. (Agric.), Advisory Officer in Farm Economics, Department of Agriculture for Scotland, Edinburgh. J. S. K.

Leake, H. M., M.A., Sc.D., Cambridge. H. M. L.

Leslie, J. C., M.A., B.Sc., Principal, East Anglian Institute of Agriculture, Chelmsford. J. C. L.

Long, H. C., B.Sc., Ministry of Agriculture and Fisheries, London. H. C. L.

Mattick, A. T. R., Ph.D., B.Sc., National Institute for Research in Dairying, Reading. A. T. R. M.

Maximov, Professor N., Institute of Applied Botany and New Cultures, Leningrad. N. M.

Metters, J. D., M.A., LL.B., Market Hill, Cambridge. J. D. M.

Murphy, Professor P. A., Sc.D., University College, Dublin. P. A. M.

Ogg, W. G., M.A., Ph.D., Director, The Macaulay Institute for Soil Research, Craigiebuckler, Aberdeen. W. G. O.

Oldershaw, A. W., O.B.E., B.Sc., County Agricultural Organizer, Ipswich. A. W. O.

Pease, M. S., M.A., School of Agriculture, Cambridge. M. S. P.

Petherbridge, F. R., M.A., School of Agriculture, Cambridge. F. R. P.

Pethybridge, G. H., B.Sc., M.A., Ph.D., F.L.S., M.R.I.A., Assistant Director, Plant Pathological Laboratory, Ministry of Agriculture and Fisheries, Harpenden. G. H. P.

Rayns, F., M.A., Director, Norfolk Agricultural Station, Sprowston, Norwich. F. R.

Read, E. C., Ministry of Agriculture and Fisheries, London. E. C. R.

Richards, E. Hannaford, B.Sc., F.I.C., Rothamsted Experimental Station, Harpenden. E. H. R.

Richardson, Professor A. E. V., Waite Professor of Agriculture, The University of Adelaide. A. E. V. R.

Richardson, H. L., M.Sc., Ph.D., A.I.C., Rothamsted Experimental Station, Harpenden. H. L. R.

Robertson, G. Scott, D.Sc., Assistant Secretary, Ministry of Agriculture, Northern Ireland, Belfast. G. S. R.

Robinson, Professor G. W., M.A., University College of North Wales, Bangor. G. W. R.

Ross, Colin D., B.Sc., County Agricultural Organizer, Exeter. C. D. R.

Russell, Sir E. J., O.B.E., D.Sc., F.R.S., Director, Rothamsted Experimental Station, Harpenden. E. J. R.

Salaman, R. N., M.A., M.D., Director, Virus Diseases of Potato Research, School of Agriculture, Cambridge. R. N. S.

Salmon, Professor E. S., F.L.S., South-Eastern Agricultural College, Wye, Kent. E. S. S.

Sampson, Miss K., M.Sc., Welsh Plant Breeding Station, Aberystwyth. K. S.

Sanders, H. G., M.A., Ph.D., School of Agriculture, Cambridge. H. G. S.

Seaton, I. W., B.Sc., Head of Plant Breeding Division, Ministry of Agriculture, Northern Ireland, Belfast. I. W. S.

Seton, Professor R. S., B.Sc., The University, Leeds. R. S. S.

Shaw, Sir W. Napier, F.R.S., 10 Moreton Gardens, London, S.W. 5. W. N. S.

Smith, A. J. M., M.A., Ph.D., Low Temperature Research Station, Cambridge. A. J. M. S.

Smith, J. Henderson, M.B., Ch.B., Rothamsted Experimental Station, Harpenden. J. H. S.

Smith, K. M., D.Sc., Ph.D., Virus Diseases of Potato Research, School of Agriculture, Cambridge. K. M. S.

Stapledon, Professor R. G., M.A., Director, Welsh Plant Breeding Station, Aberystwyth. R. G. S.

Stirrup, H. H., M.Sc., Midland Agricultural College, Sutton Bonington, Loughborough. H. H. S.

Street, A. W., Ministry of Agriculture and Fisheries, London. A. W. S.

"Student."

Theobald, F. V., M.A., F.E.S., Hon. F.R.H.S., V.M.H., (the late), South-Eastern Agricultural College, Wye, Kent. F. V. T.

Todd, A., British Dairy Institute, The University, Reading. A. T.

Vilmorin, Jacques de, Docteur de l'Université de Paris, Membre d l'Académie d'Agriculture de France. J. de V.

Wallace, J. C., Director, The Agricultural Institute and Experimental Station, Kirton, near Boston, Lincs. J. C. W.

Wallace, T., M.C., D.Sc., A.I.C., Deputy Director, Long Ashton Agricultural and Horticultural Research Station, University of Bristol. T. W.

Walton, C. L., M.Sc., Ph.D., Long Ashton Agricultural and Horticultural Research Station, University of Bristol. C. L. W

Watkins, A. E., M.A., Plant Breeding Institute, School of Agriculture, Cambridge. A. E. W.

Watson, Professor J. A. S., M.A., School of Rural Economy, Oxford. J. A. S. W.

West, C., M.A., D.Sc., Low Temperature Research Station, Cambridge. C. W.

Weston, W. A. R. Dillon, M.A., Ph.D., School of Agriculture, Cambridge. W. A. R. D. W.

White, Professor R. G., M.Sc., University College of North Wales, Bangor. R. G. W.

Williams, R. D., M.Sc., Welsh Plant Breeding Station, Aberystwyth. R. D. W.

Williams, R. Stenhouse, M.B., C.M., D.Sc., D.P.H., L.R.C.P. and S.E., Director, National Institute for Research in Dairying, Reading. R. S. W.

Woodhead, H. K., Messrs. Geo. Woodhead and Sons, Leeds. H. K. W.

Woodman, H. E., M.A., Ph.D., D.Sc., Animal Nutrition Institute, School of Agriculture, Cambridge. H. E. W.

Wright, Neville L., F.I.C., D.I.C., Office of the High Commissioner for New Zealand, London. N. L. W.

ABBREVIATIONS AND FULL TITLES OF SCIENTIFIC JOURNALS, ETC.

Agric. J. of India. Imperial Council of Agricultural Research, Government of India, Central Public Branch, Calcutta.

Agric. Prog.=Agricultural Progress. Ernest Benn, Ltd., London.

The Analyst.=Published for the Society of Public Analysts by Heffer and Sons, Ltd., Cambridge.

Ann. Agronomiq.=Annales Agronomiques. L'Institut des Recherches Agronomiques, 92 rue Bonaparte, Paris.

Ann. of App. Biol.=Annals of Applied Biology. Cambridge University Press, Fetter Lane, London, E.C. 4.

Ann. Bot.=Annals of Botany. Humphrey Milford, Oxford University Press, Warwick Square, London, E.C.

Biochem. J.=Biochemical Journal. Cambridge University Press, Fetter Lane, London, E. C. 4.

Bot. Gaz.=Botanical Gazette. University of Chicago Press, Chicago.

Can. J. Res.=Canadian Journal of Research. National Research Council of Canada, Ottawa.

Cytologia=International Journal of Cytology. Tokyo.

Deut. Landw. Gesell.=Arbeiten der Deutsche Landwirtschaft Gesellschaft. Dessauer Strasse 14, Berlin.

Hereditas=Hereditas. Berlingska Boktryckeriet, Lund, Sweden.

Inter. Rev. Agric.=International Review of Agriculture. International Institute of Agriculture, Rome.

Inter. Sugar J.=The International Sugar Journal. 2, St. Dunstan's Hill, London, E.C. 3.

J. Agric. Res.=Journal of Agricultural Research. Government Printing Office, Washington, D.C., U.S.A.

J. Agric. Sci.=Journal of Agricultural Science. Cambridge University Press, Fetter Lane, London, E.C. 4.

J. Amer. Soc. Agron.=Journal of the American Society of Agronomy. Geneva, N.Y.

J. Bact.=Journal of Bacteriology. Baltimore; and Baillière, Tindall and Cox, 7 and 8 Henrietta Street, Covent Garden, London.

J. Biol. Chem.=Journal of Biological Chemistry. Baltimore; and Baillière, Tindall and Cox, 7 and 8 Henrietta Street, Covent Garden, London.

J.C.S.=Journal of the Chemical Society. London.

J. Dairy Res.=Journal of Dairy Research. Cambridge University Press, Fetter Lane, London, E.C. 4.

J.D.A.T.I.I.=Journal of the Department of Agriculture and Technical Instruction for Ireland. Stationery Office, Dublin.

J. Ecol.=Journal of Ecology. Cambridge University Press, Fetter Lane, London, E.C. 4.

J. Econ. Entom.=Journal of Economic Entomology. Published by the American Association of Economic Entomologists, Geneva, N.Y.

J. Farmers' Club=Journal of the Farmers' Club. The Farmers' Club, 2 Whitehall Court, London, S.W. 1.

J. Genetics=*Journal of Genetics*. Cambridge University Press, Fetter Lane, London, E.C. 4.

J. Heredity=*Journal of Heredity*. American Genetic Association, Washington, D.C.

J. Hygiene=*Journal of Hygiene*. Cambridge University Press, Fetter Lane, London, E.C. 4.

J. Inst. Brewing=*Journal of the Institute of Brewing*. Harrison and Sons, Ltd., St. Martin's Lane, London, W.C. 2.

J. Linnean Soc.=*Journal of the Linnean Society*. Longmans, Green and Co., 39, Paternoster Row, London, E.C. 4.

J. Min. Agric. and Fish.=*Journal of the Ministry of Agriculture and Fisheries*, H.M. Stationery Office, London.

J.N.I.A.B.=*Journal of the National Institute of Agricultural Botany*. Heffer and Sons, Cambridge.

J. Pomol. and Hort. Sci.=*Journal of Pomology and Horticultural Science*. Headley Brothers, 18 Devonshire Street, Bishopsgate, London, E.C. 2.

J.R.A.S.E.=*Journal of the Royal Agricultural Society of England*. John Murray, London.

J. Roy. San. Inst.=*Journal of the Royal Sanitary Institute*. The Royal Sanitary Institute, 90 Buckingham Palace Road, London, S.W. 1.

J. Roy. Soc. of Arts=*Journal of the Royal Society of Arts*. Bell and Sons, Portugal Street, London, W.C. 2.

J. Roy. Stat. Soc.=*Journal of the Royal Statistical Society*. Published by the Society, 9 Adelphi Terrace, London, W.C. 2.

J.S.C.I.=*Journal of the Society of Chemical Industry*. 46-47, Finsbury Square, London, E.C. 2.

Mem. Dept. Agric. India=*Memoirs of the Department of Agriculture in India*. Agricultural Research Institute, Pusa, Government of India Central Publication Branch, Calcutta.

Phytopath.=*Phytopathology*. Published by the American Phytopathological Society, Cor. Lime and Green Streets, Lancaster, Pa.

Proc. Int. Soc. Soil Sci.=*Proceedings of the International Society of Soil Science*. International Institute of Agriculture, Rome.

Proc. Roy. Soc.=*Proceedings of the Royal Society*. Published for the Royal Society by Harrison and Sons, Ltd., 44-47 St. Martin's Lane, London, W.C. 2.

Sci. Agric.=*Scientific Agriculture* (*La Revue Agronomique Canadienne*). Published by the Canadian Society of Technical Agriculturists, Ottawa.

Scot. J. Agric.=*Scottish Journal of Agriculture*. H.M. Stationery Office Edinburgh.

Soil Sci.=*Soil Science*. The Williams and Wilkins Co., Baltimore, Maryland; and Baillière, Tindall and Cox, 7 and 8 Henrietta Street, London, W.C. 2.

Tidsskr. Planteavl=*Tidsskrift for Planteavl*. Statens Planteaviskontor, Vester Farimagsgade 20, Copenhagen V.

Trans. H. Agric. Soc. Scot.=*Transactions of the Highland and Agricultural Society of Scotland*. William Blackwood and Sons, Ltd., Edinburgh.

Trop. Agricult.=*The Tropical Agriculturist*. The Department of Agriculture, Peradeniya, Ceylon.

Welsh J. Agric.=*Welsh Journal of Agriculture*. Published for the Welsh Agricultural Education Conference, by the University of Wales Press Board, Cardiff.

Zeit. f. Indukt. Abst. u. Vererbungs.=*Zeitschrift für Induktive Abstammungs- und Vererbungslehre*. Verlag von Gebrüder Borntraeger. Leipzig.

ENCYCLOPÆDIA OF SCIENTIFIC AGRICULTURE

VOL. I

ACETYLENE—Structural formula $CH \equiv CH$, *i.e.*, C_2H_2. A gas with a strong, and, as usually prepared, very unpleasant smell. The usual mode of preparation is by allowing water to act upon a carbide, usually that of calcium, when the following reaction takes place:

$$CaC_2 + H_2O = CaO + C_2H_2$$

Acetylene is inflammable, and burns with a very hot, very bright flame, the light of which has the useful property of showing colours as in daylight. It is sometimes used for illuminating farm and other buildings, and numerous patterns of generators suitable for work with this gas are made. It is by no means a safe gas for the amateur to handle in large quantities, for several reasons; in the first place, any mixture of acetylene and air containing more than 3 per cent. and less than 82 per cent. is explosive, and explosions often occur spontaneously if the pressure should exceed 2 atmospheres. It is illegal in most countries to keep it under a higher pressure, unless some absorbent or adsorbent material is present. In comparatively recent years it has been dealt with in considerable quantities compressed into cylinders containing enough acetone and "kapok" to make it safe to go up to about 30 atmospheres. One drawback to its use as an illuminant is the fact that it requires considerable quantities of oxygen for its combustion, and so vitiates the air of enclosed spaces more quickly, per cubic foot consumption, than coal gas. An acetylene flame burning in oxygen is extremely hot, and is used for cutting metal plates and in welding. The purified gas, which has no unpleasant odour, has been used to some extent since 1924 as an anæsthetic.

ACID—A compound of hydrogen with an electro-negative atom or group of atoms, this hydrogen being replaceable either entirely or in part by a metal or group of elements equivalent to a metal, when the latter are presented to it in the form of hydroxide, a salt and water being formed. Phrased in this way the definition covers certain difficult cases, such as that of pure concentrated nitric acid, with which pure electrolytic copper shows no action, as also that of weak acids, such as carbonic and many organic acids, which do not in general attack metals. As regards the higher organic acids, however, difficulties arise, but they are rather those of bringing the hydroxide and the acid molecules into sufficiently intimate contact to secure combination. In these cases, as in those of weak acids and bases, the reaction is often of the *equilibrium* type, but as all reactions are really so, this is a minor point. Hantzsch regards strong acids as salts of the radicle hydroxonium

ACID (*Continued*)—

(H_3O)—as nitric acid (H_3O)NO_3. T. M. Lowry has recently proposed to define them as "proton donators," alkalies being "proton acceptors," the positive hydrogen ion being a hydrogen atom deprived of its single electron—*i.e.*, a proton.

Whatever view be taken as to the constitution of pure acids, we find tolerable agreement among authorities that in aqueous solution they act as if they were to a greater or less extent electrolytically dissociated in the manner pictured first by Arrhenius; thus, a nitric acid molecule may be imagined to split into two parts, a positively charged hydrogen "ion" indicated by ($H^{\cdot}$), and a negatively charged nitrate "ion" indicated by NO'_3. Since the acid properties of the solution depend on the concentration of hydrogen ions, the strength of an acid may be estimated as proportional to its dissociation constant $=\dfrac{a^2}{V(1-a)}$, where a is the degree of dissociation expressed as a decimal of unity—*i.e.*, complete dissociation—and V the volume of solution containing one molecule of the acid. This does not vary with concentration in dilute solutions, even of strong acids, but in strong solutions another law is followed. The agricultural scientist has usually to consider solutions of a dilution to which this is applicable.

During the last two decades another method of determination of acid and alkaline strength of very considerably greater delicacy has been developed—namely, the hydrogen electrode. In theory this is simplicity itself—if hydrogen or a metal is placed in contact with a solution containing hydrogen or metallic ions, a contact difference of potential is produced. By measuring this with care and accuracy, the concentration of ions in the solution can be computed. In practice, apparatus of considerable complexity is usually required for hydrogen ion concentration; a hydrogen electrode is used in the form of a hydrogen saturated covering of platinum electrolytically deposited on a gold electrode, the saturation being maintained by dipping only the tip in the solution and surrounding the rest with an atmosphere of purified hydrogen saturated with water vapour, the other electrode being of calomel in contact with saturated solution of potassium chloride. Space does not allow of further description of these apparatus; for further details see W. M. Bayliss, "Principles of General Physiology," chap. vii., Longmans, London, 1920; also Michaelis, "Hydrogen Ion Concentration," Baillière, Tindall and Cox, London, 1928, and *Encyclopædia Britannica*, fourteenth edition, "Hydrogen Ion Concentration."

The hydrogen ion concentration may be stated as (say) 10^{-6}, meaning that the solution is 10^{-6} normal in hydrogen ions; it is, however, more usual to express this by saying that the P_H is 6. P_H then is the index of the power of 10 that the normality of the solution is—*but with the sign changed.* Thus, as the P_H falls, the acidity increases; when it rises to 7 the solution is neutral, and beyond this alkaline. Note that a solution of P_H 6·5 is $10^{-6\cdot5}$, *i.e.*, $3\cdot16\ldots\times10^{-7}$ normal, *not* 5×10^{-7} normal.

For many purposes it is not necessary to determine P_H with very

ACID (*Continued*)—

great accuracy; in all such cases a series of indicators may be employed, each successive one changing colour at a different P_H, *e.g.*:

Methyl orange	changes at P_H 3·5
Methyl red ..	,, P_H 5·0
Paranitrophenol	,, P_H 6·5
Neutrality ..	= P_H 7·07
Neutral red	changes at P_H 7·5
Phenolphthalein	,, P_H 9·0

Changes in hydrogen ion concentration have the profoundest effects on both animal and vegetable life, *e.g.*, the P_H of the blood of animals cannot vary by more than about 1·5 without causing the death of the animal; similarly, the P_H of nutrient solutions affects the life of plants growing in them, and there are normally very narrow limits of P_H between which the best results are obtained. We find, however, that nature has provided means whereby such lethal changes do not normally take place in nature. These means usually consist both in the blood of animals and in the soil of weak bases and salts so mixed that they are in equilibrium with one another as regards hydrogen and hydroxyl ions, so that the addition of more merely causes the equilibrium point of one or more of these reactions to move in the opposite direction to that required for generation of the ion added, thus *nearly* as many such ions are removed from the solution as are added, and the change in P_H is small. Such action is known as *buffer* action. For further discussion of this matter see Prideaux, "Theory and Use of Indicators," Constable, London, 1917, Chap. v. Here we propose only to give a few examples of agricultural interest of the effects of varying P_H, etc.

Variation of P_H in the blood of animals is buffered by two systems of salt mixtures—namely, the sodium phosphate system, in which any increase in hydrogen ions causes recombination of dissociated sodium dihydric phosphate, reducing the number of free hydrogen ions to almost what it was before; and the bicarbonate system, in which the electrolytic dissociation of sodium bicarbonate is forced back in the reverse direction when any excess of CO_2 increases the number of HCO'_3 ions.

Proteins have a buffer action due to their ability to act as amphoteric electrolytes, and all changes depending on enzyme action are much modified by changes in P_H.

It is notable that it has been shown by K. A. Hasselbalch (*Biochem. Zeitschr.*, xlvi., 403-439, 1912) that it is the slight changes in P_H of the blood that actuates the respiratory centre, so that the intake and expulsion of breath in animals is made to accord with requirements, and that it plays some part in the mechanism of muscular activity.

Sir John Russell ("Soil Conditions and Plant Growth," p. 186, *et seq.*) considers that the division of acid soils into various classes, as done by Kappers and others, is unnecessary, and ascribes the changes encountered in various cases to buffering and amphoteric electrolytes in the soil. An acid soil absorbs more than an equivalent proportion of base from a neutral salt, leaving titratable acid.

ACID (*Continued*)—

He pictures a possible state of affairs thus:

$$\begin{matrix}\text{acid}\\\text{complex}\end{matrix} H^{\cdot}_n + nR^{\cdot}X \rightleftharpoons \begin{matrix}\text{acid}\\\text{complex}\end{matrix} \begin{matrix}H^{\cdot}_{n-y}\\R^{\cdot}_y\end{matrix} \rightleftharpoons \begin{matrix}\text{acid}\\\text{complex}\end{matrix} R^{\cdot}_n + nHX.$$

The intermediate product $\begin{matrix}\text{acid}\\\text{complex}\end{matrix} \begin{matrix}H^{\cdot}_{n-y}\\R^{\cdot}_y\end{matrix}$ can still absorb more base than it gives up, but *need* not therefore be of acid reaction, and Russell quotes cases from Hissink in which neutrality was attained when only 55 per cent. of the H_2 was replaced. The matter of P_H is ultimately connected with that of lime requirement (see Lime and Liming), but it is no *more* satisfactory by itself as a quantitative indicator than any earlier criterion, since, owing to buffer action, many soils having the same P_H have very different lime requirements.

Experiment shows that a majority of plants grow best, under laboratory conditions, in solutions having a P_H on the acid side of neutrality, while soils of the same P_H are distinctly improved in fertility by liming. As Russell points out, however, the lime has many actions quite apart from that of increasing the P_H—namely, those of replacing hydrogen and sodium in clay, and of acid hydrogen in humic acids, precipitation of soluble toxic iron and manganese, flocculation of clays, and of decreasing losses of potash and of magnesium by leaching.

ACRE—A very old land measure, being the area of a piece of land a furlong in length and one-tenth part of a furlong in width. (See Chain Gunter's.) It has remained unchanged from Anglo-Saxon times, and is the only legal acre. There are, however, many local acres, the use of which is, strictly speaking, illegal, varying between the extremes of an acre of but 2,309 square yards in Leicestershire to one of 10,240 square yards in Cheshire. The Scottish standard acre is 6,102·128 square yards, the Irish acre 7,840 square yards. The name seems to be even more ancient than the precise measure of land to which it refers; indeed, something corresponding to it occurs in all Indo-European languages, and in the root language Sanskrit. The Latin *ager* will occur to everyone in this connexion.

ADCO (proprietary process)—See Farmyard Manure, Synthetic, under Fertilizers.

ADIABATIC—So arranged that heat energy can be neither *gained* nor *lost*, *e.g.*, if a volume of gas were compressed in a cylinder through or into the walls of which no heat could pass, all the energy of compression would be used to heat the gas, and the process would be said to be an adiabatic one.

AGRICULTURAL HOLDINGS ACT—See Improvements and Other Rights, Compensation for.

AGRICULTURAL RESEARCH AND EDUCATION IN ENGLAND, THE DEVELOPMENT OF—Introductory—In the widest sense, agricultural research and education must be as old as agriculture itself. The unknown pioneers who, near the beginning of history, first turned from hunting to the systematic keeping of livestock and cultivation

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

of the soil must have observed and experimented in some crude fashion; and they must have imparted to others their glimmerings of knowledge. But when we speak of agricultural research and education, we mean of course something very different from this slow accretion of empirical improvements. We mean the progress of agricultural science by deliberate and organized investigation, and the diffusion of the results so obtained among the farming community.

Although research and education obviously have a close connection, they are nevertheless separate and distinct activities, and their development has followed rather different paths. It is convenient, therefore, to treat them separately, reserving to the end of this article a brief note upon their mutual relationship.

AGRICULTURAL RESEARCH—Agricultural research in England may be said to begin about 1840, with the names of J. B. Lawes and J. H. Gilbert. Long before then there had been speculations and experiments on such subjects as the nature of plant growth; in 1660-61 Sir Kenelm Digby delivered "A Discourse concerning the Vegetation of Plants," and in 1727 appeared Hales' "Vegetable Staticks: or an Account of some Statical Experiments on the Sap in Vegetables." Moreover, there were numerous writers on agricultural practice, of whom the best known, Jethro Tull ("Horse-Hoeing Husbandry," published 1730-31) was a practical farmer, and much more. But, broadly speaking, it is true to say that research in England began with the experiments initiated by Lawes. He was joined by J. H. Gilbert in 1843, and their association at Rothamsted continued until Lawes' death in 1900. The general introduction and use of artificial fertilizers, with which their names are mainly connected, has done much to transform agricultural practice, and may yet transform it still further.

The next fifty years showed little movement in the organization of research. In spite of the establishment of the Royal Agricultural Society's station on the Duke of Bedford's estate at Woburn, directed first by the late Dr. A. Voelcker, and afterwards by his son, Dr. J. A. Voelcker, it is broadly true to say that Rothamsted remained the only "Research Institute" (to use the modern term) where work for the advancement of agricultural science was systematically conducted. Nor did the State take any part in these activities; both Rothamsted and Woburn were financed at their origin and for many years afterwards entirely by private persons—the former by Lawes, the latter by the Duke of Bedford.

In 1889 the Board of Agriculture was established, and took over from the Committee of Council for Agriculture, among other duties, the distribution of Parliamentary grants in aid of technical instruction in agriculture and agricultural experiments. In 1889-90 it distributed for the whole of Great Britain the sum of £4,585, of which agricultural societies and associations received £680 in aid of agricultural experiments. These were mainly field experiments devoted to such practical problems as the value of artificial manures under different conditions of soil and climate; they were scarcely agricultural research as it is

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

now understood. Although the University College of North Wales at Bangor received a grant of £20 for experiments in the use of basic slag on pasture and arable land, no English University or College obtained a grant for such a purpose. Ten years later the total sum disbursed by the Board of Agriculture for agricultural education and research had risen to £7,250, of which £6,800 went to various "collegiate centres" in aid of their general work, mostly instruction, but including a certain amount of "experimental research." But this research, again, consisted almost entirely of manurial or feeding experiments primarily of local interest. Rothamsted was dealing with the soil and its fertility, but fundamental research into such subjects as animal nutrition or plant breeding was left to the spare time of under-paid teachers at Agricultural Colleges and similar institutions.

The first ten years of the twentieth century gave clear signs of a coming change. At the end of that period, the Board of Agriculture's general grant in aid of educational institutions in England had risen to more than £10,000; and it also spent a small sum in special grants for experiments and research, which included a grant to the University of Cambridge in aid of Professor Biffen's cereal breeding work. It was more important, however, that at various centres men who were, or were to become, distinguished in research were already at work. The John Innes Horticultural Institution was just being established at Merton in Surrey, with a private endowment; and William Bateson had been appointed Director. Besides Biffen, T. B. Wood and Marshall were at Cambridge, Percival at Reading, and Barker at the National Fruit and Cider Institute near Bristol. But this period is memorable above all because in 1909 Parliament passed the Development and Road Improvement Funds Act. It had become abundantly clear that no organised and adequate system of agricultural research could be set up and maintained without State aid on a far more generous scale than had been hitherto allowed. The establishment of the Development Fund, devoted primarily to the promotion of agriculture and fisheries, and endowed with a capital which shortly amounted to nearly £3,000,000, was from a purely material point of view the main origin of the present system of agricultural education and research. The eight Commissioners with whom rested the application of this large sum included A. D. Hall, at that time Director of Rothamsted, afterwards Sir Daniel Hall, Chief Scientific Adviser to the Ministry of Agriculture and Fisheries. For the first time money became available to a considerable amount not only to strengthen research staffs and to train recruits, but also to provide the laboratories, apparatus and skilled assistants required by modern research. In the summer of 1911, a general scheme for the development of research was finally settled between the Board of Agriculture and the Development Commissioners. Though the organization has grown in magnitude far beyond what was then expected, the principles adopted in 1911 still prevail, and the present structure is based upon the foundations then laid.

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

The scheme rested upon two main principles. First, agricultural research, though destined to be mainly sustained by State funds, was not transferred to the State, but continued to be entrusted to Universities and similar places of learning; the arguments for this policy need scarcely be set out in England. The second principle was the organization of research by subjects, which involved the establishment of a number of specialized institutions, each dealing with one part of the great field of agricultural science. This principle is justified by two main considerations. In agricultural research continuity is peculiarly necessary because the rapidity with which results can be obtained is strictly limited by the annual cycle of growth, and, secondly, most agricultural problems are so complex that they cannot be profitably attacked by one man working alone, but require a team of specialists in daily touch with one another. A minor but not unimportant point is that the equipment now necessary to deal adequately with any one subject is often so elaborate and expensive that it is impossible to contemplate its provision at several centres.

The outstanding feature of the scheme was, therefore, the endowment of continuous research in eleven subjects, covering more or less completely the whole field of agriculture; the work on each subject to be concentrated at one, or at most two, institutions of University rank. The subjects were as follows: Plant physiology, plant pathology, plant breeding, fruit growing (including the practical treatment of plant diseases), plant nutrition and soil problems, animal nutrition, animal breeding, animal pathology, dairying, agricultural zoology, and the economics of agriculture. A sum of £30,000 per annum was allocated for the Research Institutes, as they are now generally designated. That sum was intended to provide aid for two Institutes for plant breeding, two for animal pathology, two for agricultural zoology, one for fruit growing, and one for each of the other subjects except animal breeding; in the last case the formation of an Institute was postponed for the moment.

The foundation and permanent maintenance of Research Institutes was the main body of the 1911 scheme; but it included also four other provisions of importance. In the first place, it contemplated capital grants to assist institutions to equip themselves with the necessary land, buildings, and apparatus. Secondly, it established a system of research scholarships designed to recruit and train promising young men for permanent appointments at the Institutes. Thirdly, it provided a fund of £3,000 a year to assist special investigations undertaken outside the Institutes, so that help might be available for men of science, such as professors and lecturers at teaching institutions, who could not take research as their primary function and yet were able and desirous to undertake some particular piece of work not requiring a highly organized staff and facilities. Finally, it provided for a corps of local "Advisory Officers" to investigate problems of local importance, and to advise farmers on technical questions of a specialized nature.

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

By 1913-14, twelve Research Institutes had been established (and two minor "Research Centres"), based on the men and facilities already available; numerous capital grants for buildings, etc., had been made; and the other parts of the scheme—research scholarships, the assistance of "special researches," and a system of local investigation and technical advice—were coming into operation. The cost fell almost entirely on the State. It may be of interest to remark that in the year 1914 the Board of Agriculture spent more than £19,000 on the maintenance of the Research Institutes, and nearly £4,000 on "special researches," and that more than forty research scholarships were awarded in the three years 1911-13. Then came the War, which in this as in other directions for more than four years suspended progress.

The very considerable system of agricultural research as it exists at the end of 1930 is largely the creation of the eleven years from 1919, though it is built on the principles established and the foundations laid in 1911. It is impossible to give here any detailed history of the developments of the last eleven years, but two or three events of importance must be briefly mentioned.

Very soon after the end of the War it became clear that the recognition of agricultural research as a permanent and specialized activity involved the provision of a definite career for the men engaged in it. Otherwise it might easily become a "blind alley" occupation, neither leading to adequate remuneration in middle life, nor fitting men to take up another career. The Ministry of Agriculture accordingly used its influence to establish certain grades of research staff common to all Institutes. The Directors received personal salaries varying with the size and importance of their Institutes, but below them there were established three grades—Principal Assistants, Senior Assistants, and Assistants—with salaries fixed for each grade upon an incremental scale, and provision for superannuation. The tenure of posts in this "graded research service" may be considered to be not less permanent than the tenure of University appointments. The net result of these measures is that agricultural research in England now holds out to the man who proves his value the prospect of a career which offers no great prizes, but at least an assured, if very modest, competence.

Another striking development cannot be passed over in complete silence, though it is perhaps outside the strict limits of this article—the growth of Imperial co-operation in research. The establishment of the Empire Marketing Board with power to spend money upon agricultural research offered natural prospects of an expansion of the work already undertaken at the British Institutes, and also of mutually helpful co-operation with workers overseas. The first Imperial Agricultural Research Conference was held in London in 1927 under the auspices of the Ministry of Agriculture, and by universal consent was a great success. It has led to the establishment of eight new Imperial Bureaux (in addition to the pre-existing Bureaux of Entomology and Mycology) for the interchange of information among

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

workers throughout the Empire. Five of these eight are at English Research Institutes, one in Wales, and two in Scotland. The Bureaux in England are as follows: Soil Science at Rothamsted, Animal Health at the Ministry of Agriculture's Laboratory at Weybridge, Plant Genetics (plants other than herbage) at Cambridge, Fruit Production at East Malling, and Agricultural Parasitology at the Institute of Agricultural Parasitology, London School of Hygiene and Tropical Medicine.

At the end of 1930, the system of agricultural research in England consists of sixteen Research Institutes or Stations, besides the Ministry of Agriculture's Animal Diseases Laboratory at Weybridge. These Institutes are as follows: For soils and crops, Rothamsted Experimental Station, the Plant Physiology Research Institute at the Imperial College of Science, and the Plant Breeding Institute at Cambridge; for horticulture, the Agricultural and Horticultural Research Station at Long Ashton, near Bristol, the Fruit and Vegetable Preservation Research Station at Chipping Campden, the East Malling Research Station, the Horticultural Research Station at Cambridge, and the Experimental and Research Station at Waltham Cross (mainly for glass-house crops); for animal pathology, the Royal Veterinary College in London, the Institute of Animal Pathology at Cambridge, and the Institute of Agricultural Parasitology at the London School of Hygiene and Tropical Medicine; for animal husbandry, the Animal Nutrition Research Institute and the Small Animal Breeding Institute, both at Cambridge, and the National Institute for Research in Dairying at Reading; for agricultural economics, the Agricultural Economics Research Institute at Oxford; and for engineering, the Agricultural Engineering Institute, also at Oxford. They are mainly sustained by grants aggregating in round figures £160,000 a year from the Development Fund; although the Empire Marketing Board makes a not inconsiderable contribution, both by way of capital and maintenance grants, for research with an Imperial aspect, and one or two of the Institutes, such as Rothamsted, have some income from endowments and subscriptions. They employ in all more than one hundred trained men of science, devoting to research the whole, or nearly the whole, of their time. Besides the Research Institutes, the schemes of research scholarships, of grants for special researches, and of "Advisory Officers" for local investigation and specialist advice, continue on the lines originally planned in 1911. The first two schemes are still on much the same scale as when originally framed twenty years ago—measured in money, £3,000 a year for each; that scale has proved adequate. The last mentioned (the scheme of "Advisory Officers" stationed at Universities and Agricultural Colleges) has largely developed. It now provides at each of eleven centres in England a small corps of specialists—usually a chemist, an entomologist, a mycologist, an economist and a dairy bacteriologist, together with a veterinarian in some cases. The cost of this service, which is practically all met from State funds, is now little short of £60,000 a year. Finally, one particular enquiry ought to have separate

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

mention: a special committee has for some years been investigating Foot-and-Mouth disease at a cost of £15,000 a year. One important measure, though it is not yet actually taken, cannot be passed over in silence. The Government have announced their intention of establishing an Agricultural Research Council—analogous in many ways to the Medical Research Council—composed mainly of men eminent in the basic sciences on which agriculture rests. The purpose of the new Council will be to survey broadly the conduct and progress of research, and to apply to its service the wide knowledge and experience which no single man can possess.

On reviewing the development and present position of agricultural research in England, it may reasonably be said that during the eleven difficult years since the end of the War the State has been not ungenerous. Almost entirely at its expense, there has been created an organized system which has no rival within the British Empire, and very few outside it. That system has already conferred great benefits on British agriculture, though they may be masked by the depression of prices. The main defect of the system is probably that the provision made for investigation in the great field of animal diseases is still inadequate. There is reason to hope that that deficiency may soon be made good. When that is done the organization will be fairly complete. There is no reason to doubt that, as in the past, so in the future men will be forthcoming to inspire the life and vigour without which the best organization must be a failure.

AGRICULTURAL EDUCATION—The formal beginning of agricultural education in England may be said to date back to the end of the eighteenth century. In 1796, the Sibthorpian Chair of Agriculture and Rural Economy was established in the University of Oxford, but for nearly one hundred years it was practically amalgamated with the Professorship of Botany, and had no real influence or results in agriculture. After the establishment of that Chair, nothing substantial happened for fifty years, until in 1845 the Royal Agricultural College was founded at Cirencester. During the following forty years three Agricultural Colleges came into existence, established and conducted privately without assistance from the State. In 1887 the only institutions providing higher scientific and technical instruction in agriculture, besides Oxford and the Royal Agricultural College, were the Downton College of Agriculture, the Aspatria Agricultural College, and the Agricultural College, Hollesley Bay. About the same date certain agricultural societies and a few counties began to provide instruction, mainly in dairying, both by fixed schools and by itinerant classes, lectures, and demonstrations; for instance, the Cheshire Dairy School at Worleston, the British Dairy Farmers' Institute at Aylesbury, the Eastern Counties Dairy Institute near Ipswich, and the courses of lectures and demonstrations organized by the Leicestershire Education Committee. The Board of Agriculture from its formation in 1889 aided this kind of work by small grants, in the region of £2,000 a year for England

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

It ought perhaps to be mentioned that in 1875 the Science and Art Department at South Kensington added "Principles of Agriculture" to the list of subjects in which instruction could be given and grants earned from that Department. But owing to the general absence both of qualified teachers and of practical facilities for instruction, the Department's examination and the courses which led up to it had little or no influence upon the pursuit of agriculture as an art and a business. The beginning of a real system of agricultural education may perhaps be fixed in 1890, when the Local Taxation (Customs and Excise) Act placed at the disposal of Local Authorities a sum of about £750,000 a year (generally known as "Whiskey Money") for technical instruction. From that date onwards there was a considerable, though slow, development in both the main departments of agricultural education—the higher education provided by long courses of two or three years at Universities and Colleges, and the more elementary instruction provided by County Councils both at fixed Institutes and through peripatetic lecturers and instructors. It is unnecessary to trace in detail the events of the years between 1890 and 1908. Aided by grants, slowly increasing but still small, from the Board of Agriculture, Colleges and Universities began to interest themselves in agriculture—the College of Science at Newcastle-on-Tyne in 1891-92, Cambridge in 1892-93, Reading in 1893-94. The South-Eastern Agricultural College at Wye was established in the following year. In 1898-99, a Chair of Agriculture was established at Cambridge, and a year later the University, having organized an Agricultural Department of its own, took over all the work until then conducted by the Cambridge and Counties Agricultural Education Committee. By 1907 the Board's grants had risen to £12,000, of which nearly £8,000 went to institutions of higher agricultural education in England. Meanwhile, the instruction provided by County Councils had also developed during the three years 1907-10; the average sum spent by English counties on agricultural education was £74,000 a year, of which £12,000 came from Parliamentary grants, £29,500 from the "Whiskey Money," and the remainder from the county rates. The years from 1908 until the outbreak of war witnessed events of some importance in the development of agricultural education. In 1908 appeared the Report of the Departmental Committee on Agricultural Education, of which Lord Reay was Chairman; in 1910, the establishment of the Development Fund provided for the first time money on a relatively considerable scale; in 1912, responsibility for the supervision of all forms of agricultural education intended for persons above the age of sixteen was finally concentrated in the Board of Agriculture, who had previously divided that responsibility with the Board of Education. The best proof of expansion, though perhaps of rather a material nature, is provided by the increase of expenditure. In 1914-15 the Board of Agriculture's grant to Universities and Colleges had risen to £18,000; the English and Welsh counties were spending in all £96,000. By that time the framework of the existing system of agricultural education was created,

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

and it remained only to fill in the gaps and to strengthen the weak points.

That system aims at providing in all parts of the country access to three types of education; at Colleges (including under that term University Departments of Agriculture), at Farm Institutes, and at local classes or lectures. The Colleges give a two or three years' course of instruction; the Farm Institutes provide short residential courses, usually lasting for the six winter months, for the sons and daughters of small farmers, bailiffs, etc., who can spare neither the time nor the money for a long course; the local courses aim at bringing instruction to workers upon the land by means of evening or day classes, lectures, demonstrations, and manual instruction classes in the various skilled operations on a farm. Close communication is maintained between the Colleges on the one side and the County Councils (who are responsible for the Farm Institutes and local courses) on the other, by the division of the country into "provinces," each including a number of counties centred round a University or College, and by the institution of "provincial conferences" where College and County Officers meet at regular intervals.

The War suspended the development of this scheme. Immediately on its conclusion proposals for expenditure on a larger scale were sanctioned by the Government, and at the same time the system of grants from the Exchequer to Local Authorities was greatly simplified. The revised regulations, which are still in force, provided substantially that the Ministry of Agriculture would repay to Local Authorities two-thirds of their net approved annual expenditure on agricultural education, including the provision of technical advice for farmers, and would pay three-quarters of the capital cost of establishing Farm Institutes. The urgent need for economy in every direction which arose from the great financial depression of 1920 seemed likely to stop progress for some years. The position was, however, relieved almost immediately by the Corn Production Acts (Repeal) Act, 1921, under which a fund amounting to £850,000 was set aside for agricultural education and research in England and Wales. Since that date there has been steady progress. Excluding Veterinary Colleges, but including the women's Colleges at Swanley and Studley, there are now in England twelve University Departments of Agriculture and Agricultural Colleges, which receive grants from the Ministry of Agriculture amounting in round figures to £42,000 a year. The work done by the English County Councils includes the maintenance of thirteen Farm Institutes and the provision of a large number of local courses at a total cost of £256,000 in 1928-29, of which £172,000 represented grants from the Ministry of Agriculture. Figures are not readily available of the number of courses and students in England, apart from Wales; but during 1928-29, in the two countries together nearly 2,000 students attended courses at institutions for higher agricultural education, 950 attended courses at Farm Institutes, and nearly 14,000 attended local courses provided by County Councils. In addition, more than 9,000 lectures, demonstrations and other meetings were

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—
conducted under the auspices of the Local Authorities and their staffs. The number of whole-time instructors and instructresses employed by the Authorities was nearly 400.

One special scheme should be mentioned which is outside the sphere both of Colleges and of County Councils. In 1922 the Ministry of Agriculture, in accordance with the provisions of the 1921 Act mentioned above, initiated a scheme of scholarships for the sons and daughters of agricultural workmen and others. These scholarships are confined to (*a*) the sons and daughters of agricultural workmen or of working bailiffs, small holders and other rural workers whose means are comparable with those of agricultural workmen; and (*b*) *bona fide* agricultural workers. The awards cover the whole cost of training. On an average 120 scholarships are awarded each year, nearly all of them for courses not exceeding a year at Farm Institutes. The cost has varied round about £18,000 a year. Originally started as a five years' experiment, the scheme which proved an undoubted success, has been continued beyond the original five years, and may be taken to be now permanently established.

The system of which a brief account has been given above still needs development, and it is developing. All parts of it are reflecting the changes in agriculture itself. The tuition given in the Universities and Colleges was for many years devoted almost entirely to the natural sciences on which agriculture is founded—chemistry, botany, and so forth; now two other subjects have come into prominence, viz., the use and care of machinery, and the business aspect of agriculture, known sometimes as the economics of agriculture and sometimes as farm management. In that large part of the system which is conducted by County Councils, the main defect is perhaps a certain "patchiness"; the adequacy of the agricultural education provided varies enormously between County and County, with the character of the Councils and of their elaborates. The provision for the agricultural education of women and girls is somewhat inadequate, especially in the composite subject known as "rural domestic economy." Nevertheless, when we reflect that the system is mainly the creation of the eleven years since the War, and reflect also on the practical difficulties which confront the younger members of the agricultural population in any effort to attend a regular course of instruction, we may fairly recognize it to be a not inconsiderable achievement that every year in England more than 10,000 students receive some definite form of agricultural education. It is not enough, but it is something.

Co-ordination of Agricultural Education and Research—One further question remains: How is the whole system of agricultural research, advice, and education held together and co-ordinated? The answer can be given quite briefly. Apart from voluntary organizations such as the Agricultural Education Association, there is, first, the unifying influence of the Ministry of Agriculture; secondly, there is an organization of Councils and Committees of which perhaps the best example is the Research Council, a body which includes all the Directors of Research Institutes as well as officials of the Ministry, representatives

AGRICULTURAL RESEARCH AND EDUCATION (*Continued*)—

of the Development Commission and other Departments concerned with research; thirdly, there are the provincial conferences already described, as well as periodical conferences of the Advisory Officers; finally, every two years the Ministry holds a conference of the heads of the County staffs at a Research Institute—usually Oxford or Cambridge—so that they may meet one another, and meet research workers, to discuss subjects of common interest. If in particular cases Research Institutes do not use the services of College and County staffs where they can be helpful, or if College and County staffs are not sufficiently acquainted with the work of the Research Institutes, it is at least possible that the fault is not a fault of the organization, but of some individual.

The cost of the whole system to public funds, including the county rates, is in the region of £900,000 a year for England and Wales together. It is not a large expenditure for an industry of which the annual output is valued at more than £200,000,000 a year. The organization is young—before the War large parts of it scarcely existed, and other parts were weak and unsupported; but it may properly be claimed that it is justifying itself. The best and most encouraging proof is that, in the opinion of all qualified to judge, the attitude of the farming community itself towards research and education has completely changed during the last twenty years and is now strongly in favour of their continuing and vigorous development.

H. E. D.

AGRICULTURE, AUSTRALIA — Topography, Climate, and Vegetation — Australia has an area of 2,974,581 square miles. Topographically, it may be divided into three regions: the Western Plateau, occupying most of the continent lying west of the 135° east; the Eastern Highlands, extending as a broad belt along the whole of the east coast from Cape York Peninsula (Queensland) to Mount Gambier (South Australia); and the Central Lowlands, lying between the Western Plateau and the Eastern Highlands.

Australia has the lowest average elevation of the continents, and approximately only 150,000 square miles, or 5 per cent. of the area, has an elevation of over 2,000 ft. Approximately one-third of the continent (1 million square miles) has a rainfall of less than 10 ins., and an evaporation rate of 90 to 120 ins. per annum; one-third has a rainfall of 10 to 20 ins., with an evaporation rate of about 60 to 90 ins., and the remaining third a rainfall ranging from 20 to 160 ins., and a varying evaporation rate, but generally below 60 ins. per annum. The isohyets form approximately concentric ovals around the arid interior of the continent. The areas of heavy rainfall (over 25 ins.) are mainly along the northern and eastern coast. More limited areas are to be found in the south-west of Western Australia, and the coastal and elevated areas of Victoria and South Australia.

During the summer months (November to April) the sun is vertical over the northern third of the continent, and the great heat in the north and centre brings monsoonal rains to the tropical northern

AGRICULTURE, AUSTRALIA (*Continued*)—

regions, but the westerlies are south of the mainland, and the southern region is dry. The east coast, aided by the mountain barrier, receives rain from the south-east trade winds.

During the winter months (May to October) the 60° isotherm is north of the tropic, and the whole of the southern region comes under the influence of the rain-bearing westerlies (north-west anti-trade winds), whilst the northern region is dry. The Eastern Highlands intercept rain from both the oceanic trade winds and the westerlies, so that in these regions the rainfall distribution is fairly uniform throughout the year.

Finally, the interior of the continent lies outside the sphere of influence of both the summer monsoonal rains and the rain-bearing westerlies, but receives occasional sporadic rains from both rain systems. The rainfall of this region, which occupies much of the Western Plateau and the Central Lowlands around Lake Eyre, is light and erratic.

Rainfall and its incidence are the major factors controlling the character of the vegetative cover, and the distribution of the pastoral, agricultural, and dairying industries of Australia. The more important vegetative regions are the following:

Tropical Region—Between the coastal areas of high rainfall, which carry either tropical rain forest or savannah forest, and the arid interior, lie the hot tropical grass lands; these cover a large area of Northern Australia and (except in Queensland) are relatively undeveloped. The wetter coastal regions are suitable for cattle, and the inland areas (below the 75° isotherm and the 20-in. isohyet) for Merino sheep.

A wide range of summer-growing species (*Panicum, Andropogon, Astrebla, Eragrostis*, etc.) form the main bulk of the pasturage, and over large areas artesian water is available for stock. Along the Queensland highlands, where the rainfall is heavier and better distributed than in the tropical grass-land region, lies the tropical agricultural region where sugar-cane (*q.v.*), pineapples, bananas (*q.v.*), etc., are grown, and the northerly extension of the dairying belt, extending as far as the fertile Atherton Tableland.

Winter-Rainfall Region—This lies along the south-western and southern coasts of Australia. The coastal areas of higher rainfall are clothed with schlerophyll forest, which merges into savannah, and a characteristic type of vegetation known as mallee heath (dwarf species of eucalypts where the rainfall falls below 17 ins.).

The climate of the region is of the Mediterranean type, and wheat, sheep, fruit culture and viticulture are the principal industries.

The dominant species of pasturage in the winter-rainfall region are perennial species (*Danthonia, Stipa, Themeda*), with early ripening exotic annuals (*Bromus, Festuca, Hordeum, Erodium, Medicago*, and *Trifolium* spp.).

East Australian Region—The eastern coastal region, together with the neighbouring highlands extending from Brisbane to Melbourne, has liberal well-distributed rainfall. The natural vegetation is warm,

AGRICULTURE, AUSTRALIA (*Continued*)—

temperate forest, composed mainly of evergreen eucalypts. The cleared areas include the more important dairying regions of Australia.

The northern coastal areas are adapted to subtropical grasses, such as *Paspalum*, whilst the southern coastal areas and the highlands are particularly well adapted to the growth of European herbage plants, and to intensive agriculture and dairying.

Temperate Grass-land Region—The interior slopes of the Eastern Highlands form the temperate grass-land region. Most of this region has a fairly uniform rainfall. It lies mostly in New South Wales, and includes the Riverina, the Murray Darling Lowlands, and the Darling Downs (Queensland). The temperate grass-land region is devoted to wheat (interior slopes), and sheep on the plains.

Desert—The arid interior, forming approximately one-third of the continent, covers much of the great Western Plateau and the Lake Eyre basin. An area of true desert with a sparse vegetation of spinifex (*Triodia*) is surrounded by a broad band of xerophytic vegetation consisting of mulga (*Acacia aneura*), saltbush (*Atriplex*), and bluebush (*Kochia*). Where water supplies are available a scanty population of sheep and cattle is maintained.

SUMMARY OF PASTORAL AND AGRICULTURAL PRODUCTION—The total value of production from all sources for the year 1927-28 was £453 millions, of which agricultural, pastoral, and dairying industries contributed approximately £260 millions. The contributions of the main groups to this total were: pastoral industries, £125,068,000; agriculture, £84,256,000; and dairying, poultry, etc., £50,261,000.

The numbers of stock and the areas under crop of the principal products are summarised in the following table:

Numbers of Stock.		*Areas under Crop.*	
Sheep ..	100,827,000	*Total area under crop*	*19,219,394*
Cattle ..	11,617,056	Area under wheat	12,279,088
Horses ..	2,040,691	sown grasses	4,643,150
Pigs ..	878,207	hay	2,032,200
		oats	1,122,303
		maize	400,544
		barley	276,483
		sugar	291,300
		orchards	277,800
		vines	113,200

DISTRIBUTION OF WHEAT, SHEEP AND CATTLE INDUSTRIES—The wheat belt forms two crescent-shaped areas in south-eastern and south-western Australia. The larger area extends from the Darling Downs in Southern Queensland along the broad interior slopes of the Dividing Range in New South Wales and Victoria, to the coastal areas of South Australia. The smaller area lies inland from the Darling Ranges in south-western Australia.

The 10-in. line of winter rainfall (May to October) corresponds very closely with the inland boundary of the wheat belt, except in South Australia, where considerable areas with a winter rainfall of 8 to 10 ins. are under cultivation.

AGRICULTURE, AUSTRALIA (*Continued*)—

Sheep are widely distributed throughout Australia, but the line of maximum concentration follows very closely the 20-in. isohyet from Central Queensland through New South Wales and Victoria to South Australia. The areas of densest sheep population are in Central Queensland, the Northern Tablelands, and interior slopes of New South Wales, the Riverina (New South Wales), and Western Victoria.

The 75° F. isotherm forms approximately the northern limit of the sheep belt, and owing to the susceptibility of sheep to Foot-Rot and Liver Fluke, and the competition of dairy cattle, few sheep are found beyond the 40-in. isohyet.

Cattle are far more widely distributed than sheep owing to their ability to withstand both heat and cold, their great travelling capacity and adaptability to pioneering conditions. Their distribution ranges from the tropical coastal areas of Northern Australia, through the arid interior to the winter-rainfall region of Southern Australia. The zones of maximum concentration are along the coastal dairying areas of high rainfall in Queensland, New South Wales, and Victoria, and in the irrigation areas of the Murray Valley.

DESCRIPTION OF MORE IMPORTANT INDUSTRIES—Sheep and Wool—The sheep, more especially the Merino breed, has proved the principal source of wealth to Australia. The natural conditions prevailing throughout the temperate and subtropical portion of the continent are ideally suited for sheep and the production of fine wool. John McArthur, who arrived in Sydney in 1790, was the first to realise the possibilities of producing high-class wool in Australia. In 1796, some Spanish Merinos were obtained from the Cape of Good Hope, and McArthur procured eight of these. With these and subsequent importation from the flocks of King George III. he laid the foundation of the present-day Merinos. (See Wool.)

In 1821 wool from McArthur's flocks realised 10s. 4d. per lb. at auction in London, and in 1822 rams from his flock were sold at £300 per head. The period 1825 to 1880 witnessed the development of large sheep stations by companies or private individuals ("squatters"), and the establishment of stud flocks to produce high-grade stock, and these were largely responsible for the evolution of the Australian Merino.

At various periods Australian breeders imported breeding stock from the different flocks that had been established from the Spanish Merino—namely, the Dutch flock from Cape Colony, the English flock of George III., the flocks of Saxony and Silesia, the French flock at Rambouillet, and the Vermont (U.S.A.) flock.

Of many famous stud flocks, that of Wanganella (Riverina), established in 1858, has had an important influence on the evolution of the plain-bodied type of sheep, with a large frame and strong constitution, from the wrinkly type of Merino sheep that was formerly popular.

The marked variations in climate, rainfall, and type of pasture in the various regions of Australia have a pronounced effect on the sheep and its wool. On the tablelands of the Eastern States, and the western

AGRICULTURE, AUSTRALIA (*Continued*)—

district of Victoria, the climate and pasture are favourable for the production of fine Merino wool. The winter is long and somewhat severe, with the result that the sheep are not well-nourished throughout the year. Neither the frame nor the constitution is so robust as that of sheep on the warmer plains, but the wool is uniformly fine and dense throughout the staple. On the other hand, the warmer, open plain country of the Riverina and South Australia produces a larger, more vigorous type of sheep, but the wool, although of useful quality, is not as valuable as that produced on the tablelands.

In breeding Merinos up to their present state of excellence a skill and science have been shown that are unrivalled in the history of stock breeding. Successful Merino breeders, who have evolved types and strains of sheep which are eminently suited to the environmental conditions of their districts, are to be found in every important sheep district of Australia.

The contrast in size, constitution, density and quality of wool and length of staple between the Merinos of to-day and the animals which were secured from the Cape in 1796 is most striking. At Camden Park, in New South Wales, the descendants of the original flocks have been kept free from admixture, but they are in every way inferior to the best modern flocks.

Whilst the pure Merino forms the greater portion of the flocks of Australia, and is the dominant breed on the larger pastoral properties, British breeds are largely used in the closer settlement country and in the wheat belt. These British breeds are as superior for mutton and fat lambs as the Merino breed is for wool production. The Merino gives best results when kept in large numbers on natural pasture, but crossbreds of British breeds with the Merino are better adapted for confinement and the constant handling associated with the feeding-off of crops, and are much more suited to fat lamb production on account of their early maturity and mutton-producing qualities.

Much investigational work to determine the best types for the lamb export trade has been carried out by State Departments of Agriculture. These investigations show that a Lincoln-Merino ewe mated with a ram of the Border Leicester or Down breeds produces a lamb suited for the requirements of the export trade.

The rapid development of the sheep industry is shown by the following figures, indicating the total number of sheep in Australia at various periods:

	Numbers.
1800	6,124
1821	290,158
1850	16,000,000
1875	53,124,209
1900	70,602,995
1928	100,827,000

The maximum number of sheep was reached in 1891, when 106,421,000 were recorded, but it is considered that the flocks in 1891 were in excess of the safe carrying capacity of the country at that stage of its development.

AGRICULTURE, AUSTRALIA (*Continued*)—

The average weight of fleece has shown a steady increase, and now averages over 8 lbs. per sheep.

Merino breeders the world over depend upon Australia for stud animals to improve their flocks, and large numbers of stud stock have been exported.

Diseases—Australia has no contagious disease of stock of local origin, and on the whole the country is freer from disease than most other countries. This is due largely to the comparatively dry conditions, and the vigilance exercised by the Quarantine Department in preventing the introduction of contagious diseases.

The most serious diseases peculiar to sheep in other countries, *e.g.*, foot-and-mouth disease, are unknown in Australia. Fortunately, an outbreak of scab at an earlier period was checked. The most common diseases are fluke, worms (intestinal and lung), foot-rot, braxy-like disease, and caseous lymphadenitis. The animal health division of the Council for Scientific and Industrial Research, and the Veterinary Research Institute at Glenfield (New South Wales), have done much investigational work to show that these diseases are largely controllable.

The blowfly of sheep is a serious pest, and is responsible for large losses each year. The entomological branch of the Council for Scientific and Industrial Research is engaged in investigating the possibilities of biological control of the blowfly, and the value of deterrents.

Cattle and Dairying—In all States of the Commonwealth cattle rearing is carried out on a more or less extensive scale, the main object in certain districts being the production of stock suitable for slaughtering, and in others the rearing of dairy herds.

The rearing of beef cattle in Australia has not kept pace with the sheep industry, and may now be said to be confined on an extensive scale to Queensland, North and Central Australia, and the Kimberley district of Western Australia.

Queensland contains within its borders more than half the cattle population of the Commonwealth. Large numbers of first-class stud herds of Shorthorns and Herefords are kept in Queensland, New South Wales, and Victoria, and the nucleus of these herds was imported from the best stock obtainable in Britain. The sums paid for first-class sires astonished English breeders of the day. Thus, £2,500 was paid for Oxford Cherry Duke (32016), and, in 1878, 2,450 guineas was given for Duke of Derrunut 24th. As much as £27,000 was paid for a herd of thirty-seven head.

A considerable trade in frozen beef has developed, and during the five years ending 1928 the United Kingdom took 59 per cent. of the total shipments, which were valued at £7,455,469. The expansion of the export trade will lead to a better utilization of the tropical and subtropical portions of Australia.

Dairying—The dairying industry extends from the Daintree River in North Queensland (latitude 18° 15″ S.) throughout the coastal belts of Queensland and New South Wales, and into certain inland

AGRICULTURE, AUSTRALIA (*Continued*)—

districts of those States, throughout Victoria and Tasmania, the coastal areas of South Australia, and the south-western division of Western Australia. Its geographical distribution is governed by rainfall and soil conditions, and is practically confined to areas of comparatively high rainfall (over 25 ins.), except where its development is aided by irrigation. That temperature and humidity are not major governing factors is illustrated by its expansion in Queensland, where the most extensive development under tropical conditions is to be found in any part of the world. Prior to 1888 the industry was confined to the supply of products for local consumption, and under these conditions the progress of the industry was necessarily limited. The industry, however, received a great impetus when improvement in the processes of refrigeration made possible the development of the export trade in butter. (See Refrigeration.)

The Australian climate offers certain competitive advantages, in that stock thrive in the open throughout the year, but the industry was formerly handicapped by intermittent droughts, poor breeds of dairy cattle, and general ignorance of scientific methods of production and manufacturing. Since the establishment of the export trade, consistent efforts have been made by farmers, in co-operation with State Governments, to overcome these disadvantages.

Stud cattle were imported in large numbers by private breeders and by State Departments of Agriculture, and many first-class stud herds of Jerseys, Ayrshires, Dairy Shorthorns, Friesians, Guernseys, and Red Polls have been established.

There has been a marked improvement in the average yield of milk as a result of the increasing use of pure-bred sires, herd testing, and methods of feeding.

The results of herd improvement have not yet been fully felt, as most herd-testing systems are of too recent origin to have enabled all their members to build up the standard of mature cows in their herds. The results of herd testing have been most pronounced in Victoria, where 63,277 cows were under test during the season 1928-29. The average yield of milk for the cows under test was 508 gallons, and the mean yield of butter fat 222·4 lbs. per cow.

Marked improvements have also taken place in the technical processes of manufacture of butter, cheese, preserved and dried milk products, during the past quarter of a century. New South Wales has shown the most marked advances in the improvement of manufacturing processes, and maintains a highly efficient scientific and technical service for the control of factory processes.

An enlightened system of dairy supervision by State Departments of Agriculture has been developed concurrently with these improvements, whereby the interests of consumers, both at home and abroad, are protected, and the dairy farmer is encouraged to stimulate production by the rational feeding of stock, herd testing, use of pure-bred sires, and the elimination of disease.

One achievement of Australian breeders is the evolution of a distinct breed of dairy cattle—the Illawarra Dairy Shorthorn. In an

AGRICULTURE, AUSTRALIA (*Continued*)—

official test one representative of this breed, Melba XV. of Darbalabra, produced 3,252 gallons of milk, with 1,614 lbs. of butter fat, in twelve months.

The introduction by Baron von Mueller, in 1891, of the Southern American grass, *Paspalum dilatatum*, has had an extraordinary influence on the dairy production of New South Wales and Queensland. This was first grown at Wollongbar in New South Wales, and spread rapidly until more than a million acres of first-class land in the Northern Rivers district was covered with the grass. It is the only grass capable of competing with the numerous aggressive weeds that strove to take the place of the rain forests of the famous Northern Rivers dairying district when this area was first opened up.

The dairy industry is ideally suited for intensive production, as it is conducted principally in regions of liberal rainfall and fertile soil, and because it is composed of a large number of individually small units. The industry is entering an intensive stage of development, and the output will be largely increased when the effect of present policies for encouraging herd testing, use of pure-bred sires, and improved methods of feeding have had time to materialize. Moreover, the carrying capacity of the dairying country will be greatly enhanced by the more general use of artificial fertilizers on pastures, the extensive use of sown pastures, and the adoption of improved forms of pasture management.

The Wheat Industry—The conversion of the savannah country into wheat lands began when the early squatters in south-eastern Australia allowed their cattle and sheep to roam over vast expanses. The trees were first ringbarked to provide additional grass for stock. Eventually, as settlement extended, the pastoral estates in the better rainfall areas were subdivided into wheat farms, and the dead trees were grubbed and burnt.

Large areas of the cereal lands of Australia were fairly easy to clear, partly because they were not derived from the dense forest which clothes the coastal areas, and partly because of the pioneering work of the early pastoralists.

The increasing demand for wheat land ultimately led to the conversion of large areas of mallee heath to wheat farming. The mallee covers extensive tracts in South Australia, North-Western Victoria, and Western Australia. It consists of a dense scrub of shrubby eucalypts with thickened root stocks from which arises a series of stems. Wheat was destined to grow on millions of acres where sheep and cattle had never browsed. The mallee roller, consisting of a heavy boiler, propelled through the scrub by a team of bullocks, broke the mallee shoots at ground level, and the fire stick and stump-jump plough completed the clearing.

In 1876, R. B. Smith of Ardrossan, South Australia, constructed a multiple furrow plough with shares which worked independently of each other in a frame. Any one share striking an obstruction or a stump rose automatically, passed over the obstruction and re-entered

AGRICULTURE, AUSTRALIA (*Continued*)—

the ground. In course of time the mallee stumps decayed or became loosened by ploughing. Without the invention of the stump-jump plough the mallee areas might not have been developed for wheat, owing to the expense of clearing and grubbing.

The wheat industry is the second largest industry of Australia. Considerable expansion, both in acreage under crop and in yield per acre, is inevitable. Notwithstanding the continued expansion into drier areas, the yield per acre has materially increased, mainly owing to research and educational work by State Departments of Agriculture and by various Research Institutes. Moreover, the rapid development of labour-saving machinery has established the industry on a sound economic basis. The level character of the wheat lands, and the dry, hot weather experienced at harvest enables combine harvesters to strip, thresh, winnow, and bag the grain in one operation from the standing crop. (See Thrashing.)

Australian engineers have played a prominent part in the development of modern harvesting machinery. The "stripper," a modern adaptation of the machine described by Pliny as being in use in ancient Gaul, was invented by Ridley in 1846. It revolutionised the industry, and reduced the cost of harvesting from 3s. 6d. to 6d. per bushel. In 1884, H. V. McKay invented the combine harvester, which stripped and winnowed the grain in one operation. Various improvements have been effected, and an "auto-header," operated by a tractor fitted on the machine, has been developed which in one operation strips, winnows, and bags the produce of 40 to 50 acres a day. The Australian combine has been exported to Russia, Argentina, Canada, and the United States. With the use of such labour-saving machinery, the Australian wheat grower, although 11,000 miles from his main market, can grow wheat in competition with the world.

Departments of Agriculture and Research Institutes have devoted much attention to the problem of increased yields per acre. It was recognized that the rainfall during the crop-growing period was the most important factor in limiting the yield of wheat. Cultural methods were gradually developed whereby a maximum of moisture is conserved in the soil, and a system of dry farming was evolved which is probably unexcelled in any other wheat-growing country.

The basis of the system is a long period of bare fallow during the season preparatory to the sowing of the crop. (See Fallow; also Agriculture, Canada.) On certain types of land—*e.g.*, the Wimmera district of Victoria—this preparation extends over eighteen months. A loose, shallow mulch is continuously maintained in the fallow throughout the summer months, and weeds are controlled by frequent cultivation with scarifiers, spring-tooth cultivators, and harrows. The main objective is conservation of soil moisture and the carrying forward of a store of subsoil moisture to supplement that which falls during the growing period.

A result of almost equal importance is the large amount of nitrate nitrogen accumulated in the soil during the period of fallowing as a result of the activity of nitrifying bacteria. The quantity of nitrate

AGRICULTURE, AUSTRALIA (*Continued*)—

nitrogen formed in the fallow often exceeds 100 lbs. per acre, equivalent to 500 lbs. of sulphate of ammonia. (See Nitrification.)

Other incidental advantages arising from fallowing are the reduction in soil-borne fungus diseases, the production of a fine consolidated and clean seed bed for the young wheat crop, and the more even distribution of farm labour over the year.

Throughout the wheat belt phosphatic fertilizers, especially superphosphate, give an extraordinary response. Investigational work has clearly established the general deficiency of Australian soils in available phosphoric acid, and has shown that an application of soluble phosphate to wheat encourages deep rooting, promotes vigorous, early growth, increases the percentage of ear-bearing tillers, hastens the maturity of the crop, and markedly lowers the transpiration coefficient (water requirement) for grain, and thus increases the effectiveness of a limited rainfall. (See Wheat; Manuring, Principles of.)

Research work has established the fact that nitrogenous fertilizers are unnecessary for wheat where bare fallowing is practised, on account of the heavy accumulation of nitrate nitrogen during the fallowing period. Only in the regions where the rainfall during the crop-growing period exceeds 15 ins., and where wheat is grown in continuous rotation with other crops, have nitrogenous manures given favourable results.

The water requirements for wheat have been worked out at typical centres in the wheat belt, and it has been shown that for rainfalls of 10 to 15 ins. during the growing period, each inch of rain transpired by the crop produces approximately 3¼ bushels of wheat per acre. The transpiration coefficient for wheat (390 for dry matter, 1,090 for grain) is considerably lower than that recorded for wheat in the United States, and slightly higher than the transpiration ratios recorded in Central Europe.

Close correlations have been established between the intensity of the physical environment, as measured by mean air temperature saturation deficit of the air, and evaporation from a free water surface, and the transpiration coefficient of wheat.

The studies of water requirements have shown that the water cost of producing dry matter can be reduced materially by the use of soluble phosphates, by adjusting the date of sowing to avoid rank early growth, and by the use of early maturing varieties characterized by a high percentage of grain to straw.

The production of improved varieties that are well adapted to their environment has been an important factor in the achievement of increased wheat production. The European varieties grown at the outset were quite unsuited to the Australian climate, on account of their long period of growth. The hybridization of imported wheats, followed by selection along Mendelian lines, was therefore necessary in order to create varieties that were suitable to the climatic conditions of Australia.

The pioneer worker in this field was William Farrer. Farrer's work, which commenced in 1886, was remarkably successful, and workers from many countries came to study his methods. In 1898,

AGRICULTURE, AUSTRALIA (*Continued*)—

in a paper to the Australian Association for the Advancement of Science, he described the segregation and recombination of plant characters, in the second generation of cross-bred progeny, and the methods he used for securing homozygous types. Through his efforts the varieties of wheat of his generation were greatly improved in yield, milling quality, drought resistance, and rust resistance, and many of his creations are still grown extensively in the wheat belt. It is estimated that the wheat varieties produced by Farrer have added millions of bushels annually to the wheat yield of Australia.

The new cross-bred varieties produced by various wheat breeders during the past twenty years have almost entirely supplanted those in cultivation a generation ago. Research workers have devoted much attention to the investigation of fungus diseases, which materially lower the yield of wheat. The earliest and most prominent investigator in this field was McAlpine, whose classic contributions on the Rusts and Smuts of Australia, and on Take-all (*Ophiobolus graminis*), are well known. (See Diseases of Cereals, under Wheat; Seed, Transmission of Plant Diseases by.)

For many years plant breeders have endeavoured to produce varieties that were resistant to Rust (*Puccinia graminis*) and Flag Smut (*Urocystis tritici*). Success was achieved in the latter case by the production of a cross-bred Nabawa, but the problem of breeding for Rust resistance was more difficult, and not until recently was the reason for the failure clearly understood.

Stakman's work at Minnesota showed that there were a large number of biologic forms of wheat Rust, each of which could be identified only by its reaction on certain host varieties. Following on Stakman's work, Waterhouse of New South Wales isolated six indigenous biologic forms of Rust, and one form which has been found in other countries. He showed that the cross-bred variety, Thew, was resistant to three of these biologic forms, whilst another variety, Canberra, was resistant to the remaining three. By crossing these two varieties he was able to produce a new variety, Euston, which is resistant to the six indigenous strains. An American variety, Webster, was shown to be completely resistant to the introduced species of Rust, and crosses between Euston and Webster have been made which promise to be completely immune to the seven biologic forms of Rust now found in Australia. The solution of the problem of producing Rust-resistant varieties for Australia has been materially advanced by Waterhouse's work.

A contribution to the control of wheat Smut (*Tilletia tritici*) was the demonstration by Darnell Smith (New South Wales) of the efficacy of copper carbonate dust. This method of control was first developed in Australia, and is now largely applied in the United States of America. (See Insecticides and Fungicides.)

As a result of the extensive research work carried out by Australian workers on all phases of wheat culture, there has been a consistent increase in the average yield per acre for the past three decades, notwithstanding the continuous expansion of the wheat belt into drier

AGRICULTURE, AUSTRALIA (*Continued*)—

and poorer areas. Thus, the average yield of wheat for South Australia for the decade ending 1926 was 12·44 bushels, as compared with 4·74 bushels per acre for the decade ending in 1896. Similarly, in Victoria the average yield has increased from 7·6 to 14·4 bushels per acre during the same period. In the Wimmera district of Victoria, where the area under crop (600,000 acres) has not materially altered during the past twenty years, the average yield per acre has increased from 7·08 to 20·9 bushels.

Fruit and Viticulture—The area under orchards is 278,000 acres, and under vines 113,000 acres. Australia possesses few indigenous edible fruits, and none of these is of commercial value. The development of the fruit industry is a record of the acclimatization of temperate and tropical fruits from other lands. Practically all types of fruit are grown, from the banana, pineapple, pawpaw, mango, and guava of tropical Queensland, to the wide variety of European fruits in the temperate regions of Australia.

Prior to the development of refrigerated transport, the progress of fruit growing was dependent upon local demand. With the opening up of the export trade in apples, extensive areas were planted in Tasmania, Victoria, New South Wales, and Western Australia. More than one-third (98,000 acres) of the total acreage under fruit is devoted to apples, and the value of production for 1928 was £2,837,000. Other fruits grown extensively are oranges (48,000 acres), peaches (26,000 acres), and bananas (20,000 acres). (See Refrigeration.)

Irrigation settlements devoted primarily to fruit and vines have been developed along the Murray Valley and in areas watered by the Goulburn River (Victoria) and the Murrumbidgee in New South Wales. The first extensive irrigation scheme was that established by Chaffey Bros., who obtained a concession from the Victorian Government and commenced a large scheme at Mildura. Serious difficulties were met with—inexperience in the use of suitable varieties of fruit and vines, insufficient pumping power, and difficulties arising from excess of soluble salts in the soil. Eventually these difficulties were overcome, and a prosperous irrigation settlement supporting 6,000 people was established.

Considerable impetus was given to irrigation when the Victorian Government vested the conservation of water and the control of irrigated lands in the State Rivers and Water Supply Commission. The Commission did excellent work in repurchasing large estates, subdividing them into areas suited for irrigated agriculture, and providing for easy terms of payment. Irrigated settlements were concentrated on fertile land as near the source of water supply as possible, to lessen the losses of water by seepage and evaporation, and to lower the cost of irrigation water. A system of beneficent control of all new settlements was established under which scientific and technical officers attached to the Agricultural Department gave continuous advice and instruction on all phases of irrigated agriculture.

One of the largest irrigation projects is that of the Murrumbidgee

AGRICULTURE, AUSTRALIA (*Continued*)—

settlement, which includes a large dam with an estimated capacity of flooding 772,000 acres to a depth of one foot. Upwards of 200,000 acres of land are available for fruit, dairying, stock raising, rice and vegetable growing.

The opening up of irrigated fruit lands has brought about marketing difficulties on account of the large surplus production. To find an outlet for these fruit products attempts have been made to open up overseas markets for fresh citrus, canned fruit, and dried fruit, on the demand for which the future extension and welfare of the settlements depend.

Large canning factories have been established in Victoria and New South Wales to deal with fresh fruit. The dried fruits industry began in a small way, but it was not until the settlement of the Murray Valley that the industry developed to commercial proportions. Raisins, sultanas, and Zante currants are chiefly treated, but apricots, peaches, figs, prunes, pears, are also handled. The rapid progress of the industry is attributed to the practical monopoly secured within the Commonwealth by the imposition of a tariff on all imported dried fruits which can be produced locally, and to its organization for marketing by the formation of the Australian Dried Fruits Association in 1907. Since the War, this Association has been endeavouring to stimulate overseas demand.

The viticultural industry was established at a very early period, but its progress was considerably checked in Victoria and New South Wales by the introduction of *Phylloxera*. Experimental stations are established by the Victorian and New South Wales Governments to raise *Phylloxera*-resistant stocks, and to investigate the affinity of the various resistant stocks to the varieties of vine cultivated in Australia. Eventually the problems relating to reconstitution on *Phylloxera*-resistant stocks were solved, and large areas of viticultural land formerly infested with *Phylloxera* have been reconstituted. (See Insects, Measures of Controlling; Plant Diseases and Pests, Legislation with Reference to.)

By a vigilant system of inspection *Phylloxera* has been kept out of South Australia. The area under vines is 113,000 acres, of which 51,000 acres are in South Australia. The climate and soil are eminently suited for the growth of the vine and the production of wine.

The production of wine (17 million gallons) has not increased as rapidly as the soil and climate would appear to warrant, partly because the Australians are not wine-drinking people and do not provide a large local market, and partly because of the difficulties of securing an overseas market in the face of the competition of well-known and long-established European wines.

Investigational work has greatly assisted the development of these industries. The State Agricultural Departments have maintained technical services in fruit culture and viticulture, and the Research Stations controlled by the Council for Scientific and Industrial Research at Merbein (Victoria) and Griffith (New South Wales) have made substantial contributions to soil fertility problems associated with irrigated agriculture movement and control of soluble salts in the

AGRICULTURE, AUSTRALIA (*Continued*)—

soil, methods of processing fruit and of irrigation. The work by the State Departments of Victoria and New South Wales on *Phylloxera* control has already been referred to.

Recent work on the problem of bitter pit in apples has been particularly helpful to growers. This trouble has caused serious losses in the transport of apples overseas. The Division of Plant Industry has established the fact that bitter pit is due to apples being picked for the export trade before they have reached a certain stage of maturity, that a simple iodine test for starch is a guide to maturity, and that the trouble may be averted by picking after they have arrived at the stage at which they are no longer susceptible.

An interesting recent development in the irrigated fruit areas of the Murrumbidgee is the development of commercial rice growing. Experimental work on rice culture was conducted on the Yanco Experiment Farm for some years, but it was not till 1924-25 that an attempt was made to grow rice on a commercial scale. In that season, 153 acres were cropped for a total yield of 16,240 bushels. In 1927-28 the area under rice was 9,901 acres, and the production 879,113 bushels —an average yield of 88·9 bushels per acre. (See Rice.)

Sugar—The production of raw sugar in Australia for 1927-28 was 509,000 tons, manufactured from 3,764,439 tons of cane. Ninety-three per cent. of the cane is grown in Queensland, and the bulk of this is raised in the tropical coastal districts. The industry has experienced many vicissitudes owing to labour difficulties, use of unsuitable cane varieties, losses through insect and fungus pests. (See Sugar-Cane.)

The technical difficulties incidental to the establishment of a new agricultural industry were largely overcome by the assistance of the Bureau of Sugar Experiment Stations. This organization has rendered excellent service to the sugar industry by demonstrating the value of improved methods of cultivation, use of green manures, lime, and fertilizers, together with the improvement and distribution of improved varieties of cane.

As a result of the systematic study of cane cultivation in Queensland the sugar content of cane and the yield per acre have substantially improved. The average yield of cane for the decennial period 1927-28 was 17·9 tons per acre, as compared with 16·6 tons for the previous decennium. Again, the improvement in the sugar content of the cane is shown by the fact that the average amount of cane required to produce a ton of raw sugar for the past three years was 7·53 tons as compared with an average of 8·75 tons for the decennium ending 1918.

The Commonwealth Government has assisted the industry by means of bounties and excise tariff with a double object of benefiting the industry and diminishing the employment of coloured labour.

A cane harvester recently invented in Queensland gives promise of substantially reducing the costs of production per acre.

Sugar-beet is grown on a small scale in the Maffra district of Victoria.

AGRICULTURE, AUSTRALIA (*Continued*)—

ORGANIZATION OF RESEARCH IN AGRICULTURE—State Departments of Agriculture—Each of the State Governments maintains a Department of Agriculture with scientific and technical staff to assist the general development of the agricultural and livestock industries. The organization of these Departments varies in detail, but in the more populous States, *e.g.*, New South Wales and Victoria, very extensive research and extension services are provided in agricultural chemistry, agronomy, agrostology, plant genetics, plant pathology, entomology, fruit culture, viticulture, dairying, animal husbandry, and veterinary science.

Experimental and Demonstration Farms have been established by each Department in the more important climatic regions to demonstrate the value of approved practices in the production of farm crops and of livestock husbandry. Agricultural Colleges were established at Roseworthy, South Australia (1882); Dookie, Victoria (1885); Hawkesbury, New South Wales (1888); Gatton, Queensland (1895); and Muresk, Western Australia (1926), to provide instructional work in agriculture, and to promote more scientific methods of agriculture, stock husbandry, and dairying.

University Schools of Agriculture—Schools of agriculture have been established at the Universities of Adelaide, Brisbane, Melbourne, Sydney, and Western Australia, for the training of research workers and specialists in agriculture. In 1925, the University of Adelaide established the Waite Agricultural Research Institute as the result of a bequest of £100,000 to the University by Mr. Peter Waite for the promotion of agricultural research. The Waite Institute conducts extensive researches in agronomy, agrostology, plant genetics, agricultural chemistry, entomology, and plant pathology, and in co-operation with the Commonwealth Council for Scientific and Industrial Research maintains a division of soil research.

Commonwealth Council for Scientific and Industrial Research—In 1926, the Commonwealth Government reorganized the Institute of Science and Industry, and established the Council for Scientific and Industrial Research, to conduct researches on problems relating to the development of the primary and secondary industries. As the primary industries were of such outstanding importance, the main efforts of the Council have been directed to the scientific problems associated with primary production.

From its inception the Council has sought to co-operate and collaborate with State Departments of Agriculture and Universities in the development of this important field of research, and appointed a Standing Committee on Agriculture comprising the permanent heads of the State Departments of Agriculture, to ensure complete co-operation and collaboration with State institutions in the development of agricultural research in Australia.

Six major divisions were established by the Council to attack major sections of the work—animal health, animal nutrition, plant industry,

AGRICULTURE, AUSTRALIA (*Continued*)—

entomology, soil science, and forest products. Shortage in scientific personnel adequately trained in sciences broadly classed as biological has been a limiting factor in progress. Nevertheless, the progress made has been very satisfactory.

Problems of animal health and animal nutrition are naturally of great importance in a country so dependent on livestock as Australia. Though Australia is freer from stock diseases than most other countries, and does not suffer from such highly infectious diseases as foot-and-mouth disease, rinderpest, etc., nevertheless disease exacts a heavy toll annually from the livestock industries. The ravages of blowfly, liver fluke, braxy, caseous lymphadenitis, and other diseases in sheep cause, in the aggregate, losses amounting to millions sterling annually. Similarly, in cattle, heavy losses are caused by tick, worm nodules, buffalo fly, pleuro-pneumonia, contagious abortion, mammitis, and tuberculosis.

Some of these pests, *e.g.*, buffalo fly in cattle and blowfly in sheep, are being attacked by the entomological division of the Council for Scientific and Industrial Research, with a view to ultimate control by biological and other agencies.

The attack on problems of animal health will be greatly facilitated by the generosity of F. D. McMaster, a prominent pastoralist of New South Wales, who donated to the Council for Scientific and Industrial Research a sum of £20,000 for the establishment of a Laboratory of Animal Health at Sydney University.

The Division of Animal Nutrition has as its main objective the study of wool production by the Merino sheep, and the determination of the fundamental physiological and chemical factors involved in the production of wool. (See Wool.)

The Division of Plant Industry devotes particular attention to the problems of plant introduction, plant diseases, plant genetics, storage of fruit, and agrostology.

The Division of Entomology is specially interested in the problems associated with the biological control of insect pests and noxious weeds. A substantial grant has been made by the Empire Marketing Board to test out on a large scale the possibilities of biological control. (See Insects, Measures of Controlling; and Plant Diseases and Pests, Legislation with Reference to.)

The Division of Soil Research is concerned with problems of soil classification and soil survey, and the study of soil fertility problems in irrigated settlements.

The Division of Forest Products is concentrating on the problems associated with the seasoning and preservation of timber, and the utilization of by-products of the timber industry.

The Council for Scientific and Industrial Research is not only working in close collaboration with Departments of Agriculture and Universities, but a close link has been forged with British Research Institutes through the Imperial Bureaux and the Empire Marketing Board. A number of co-operative investigations are in progress between the Empire Marketing Board and the Council.

AGRICULTURE, AUSTRALIA (*Continued*)—

APPLICATION OF RESEARCH—The cumulative results of the scientific research conducted by the Departments of Agriculture, Research Institutes, and the Council for Scientific and Industrial Research are reflected in the progressive development of the agricultural and livestock industries. Much pioneering work had to be done by agricultural institutions to adapt crops, fruits, and pasture plants of temperate, subtropical, and tropical countries to the varied climatic and soil regions of Australia, and to ensure protection of such crops from attack of indigenous and introduced insect and fungus pests.

The results of scientific research are apparent in the wheat industry. The wheat crop has been intensively studied by agronomists, plant breeders, plant physiologists, chemists, and soil workers. Notwithstanding the continuous expansion of the margin of cultivation into drier country to meet the needs of settlement, there has been a steady increase in the mean yield per acre during the past two decades.

Much attention has been devoted to the improvement of grass land by plant introduction, top dressing of pastures, sowing down of improved species and strains of pasture plants, and pasture management. As a result the stock-carrying capacity of the grass lands, especially in regions of liberal rainfall, has been greatly augmented.

The continuous extension of settlement has necessitated the harnessing of the water resources and the development of extensive schemes of irrigation, particularly along the Murray Valley. These developments necessitated much scientific investigation to determine the appropriate varieties of fruit and pasture plants for each soil type, and the study of soil fertility problems associated with irrigated agriculture.

The output from dairying has rapidly increased during the past decade, due mainly to improved systems of feeding stock, the use of pure-bred sires, the extension of herd testing, and the reduction of disease. Moreover, the quality of manufactured dairy products has been raised to a high standard by the technical control exercised by the State Departments of Agriculture in factories and on farms.

Limitations of space prevent other than passing reference to certain scientific investigations of great economic significance.

The recently constituted Division of Animal Nutrition has shown that keratin, which constitutes the wool fibre, differs from other naturally occurring proteins mainly in its unusual assemblage of amino acids, and in particular cystine, which constitutes 13 per cent. of wool fibre. The sheep is unique among animals in its extraordinary demand for cystine, the supply of which varies in fodder plants, and at certain periods of the year provides the first limiting factor to wool production. It has been demonstrated that the yield of wool may be increased materially at low economic cost by supplementing the natural pasture with a cystine-rich diet, at periods of the year when the pasture is dry and of comparatively low nutritive value.

Further, the carrying capacity of large areas of country, normally deficient in phosphate, may be substantially increased, with marked benefit in the health of stock, by the use of appropriate mineral licks

AGRICULTURE, AUSTRALIA (*Continued*)—
in regions of light rainfall, and by the top dressing of phosphates in regions of heavy rainfall.

A particularly interesting example of the application of scientific research to problems of primary production is the biological control of prickly pear. Prickly pears were brought to Australia by the early colonists without their natural enemies, and remained exempt from injury by native insects. They therefore spread with amazing rapidity in their new environment. In 1925 the pear menace reached its climax, when 60 million acres of more or less fertile land in Queensland and New South Wales were infested with the pest.

Much intensive research has been conducted to thoroughly test out the best methods of eradication by mechanical means, by chemical agencies, and by biological control. In 1919, the Governments of the Commonwealth, Queensland, and New South Wales agreed to co-operate in investigating the possibilities of applying methods of biological control. The first step was to search the cactus world for predators and parasites of the Opuntias, import, acclimatize, and test them against crops of economic value to prove that they would not be harmful to plants other than the Opuntias. Large numbers of predators have been introduced, acclimatized, and tested, and among these the caterpillar of a brown moth called *Cactoblastis cactorum* has proved most successful and destructive. During the 1929-30 season over 2,000,000,000 eggs of this parasite were liberated in the prickly pear belt. Considerable areas of heavily infested land have been completely reclaimed with the aid of this parasite, and are now under cultivation. Provided the *Cactoblastis* can be kept free from native or introduced parasites, there is every reason to believe that an area of fertile territory as large as that of England will ultimately be reclaimed. (See Insects, Beneficial; Insects, Measures of Controlling.)

A. E. V. R.

AGRICULTURE, BRITISH, HISTORY OF—The origins of agriculture are, of course, to be sought outside Britain. The probability is that the earliest cultivation occurred in Western Asia (Phœnicia, Syria, etc.), but it is probable that independent beginnings were made elsewhere—for example, in Africa. The earliest known crop relics, which are those of six-rowed barleys and of the Emmer type of wheat, are at least as old as 5000 B.C.

It was believed formerly that civilization passed through a pastoral age before tillage began, but this view is not supported by the archæological evidence. There is nothing to show that the early Asiatic corn growers possessed domesticated animals. The first pastoralists probably lived farther west, beyond the Caspian Sea, in South Russia and Turkestan. Their earlier relics contain the bones of the sheep, ox, goat, and pig, while those of domesticated horses and camels occur later on. The combination of crop with animal husbandry, which must have been one of the great steps in the progress of early civilization, was probably effected by a south-westward movement of the pastoralist peoples. The Neolithic Sumerian

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

inhabitants of Mesopotamia, between 4000 and 3000 B.C., were already mixed farmers, and possessed horses as well as the earlier domesticated classes of stock.

In Europe there was neither tillage nor livestock (if we except the dog) during the Palæolithic period, which ended about 6000 B.C. During the succeeding Neolithic Age, however, which lasted in Central Europe until 2500 B.C., there was a well-developed agriculture. The Neolithic lake dwellings of Switzerland, for example, have yielded remains of wheat, barley, millet, and flax, along with the bones of small and obviously domesticated types of cattle, sheep, goats, pigs, and dogs. There is no evidence of the evolution of these crops and animals from native European species, and hence it is the generally accepted view that the Neolithic agricultural peoples migrated from Asia into Europe, bringing their crops and stock with them. There is much other evidence in support of this view.

The first wave of Neolithic people arrived in Britain about 2000 B.C., having possibly been driven westward by a fresh inroad of more advanced peoples from Asia. They settled along the western side of England and Scotland, as well as in Ireland. At the time in question there was probably still a land-bridge between Kent and the Continent, or, at the most, only a narrow lane of water between. The settlers were thus able to bring their livestock as well as their seeds. Round the sites of their hamlets are to be found the traces of small and irregularly shaped patches of arable ground, which could have been tilled only by means of hand tools. In these fields, or rather gardens, they probably grew corn; indeed, charred grain has been noted among the remains from a Neolithic site in Scotland of about the time in question. The burial mounds (long barrows) of these people contain the bones of all the domesticated animals mentioned above, and all conforming closely to the Continental Neolithic forms.

About 1150 B.C., there arrived the Goidels, or Gaelic-speaking Celts, and from about 450 B.C. the Brythons, or Welsh-speaking division of the Celtic race. The former penetrated the whole of the British Isles, while the latter did not reach northern or north-western Scotland, or Ireland or the Isle of Man. The Gaels probably brought with them the knowledge of a small and primitive plough drawn by ponies; the Brythons may have introduced the heavier and more efficient "long" plough drawn by oxen. One or other of the Celtic invaders appears to have introduced the oat, which is not found in Neolithic deposits and is probably of European origin. The earliest British specimens of this grain, found in Wiltshire, are thought to date from 500-400 B.C. The Brythons may also probably have brought some of the larger types of cattle and sheep that were characteristic of the Bronze Age on the Continent.

The Roman occupation was not associated with any considerable new settlement, and probably made very little difference to the agriculture of Britain. Roman villas indeed must have been numerous, and the domestic life of the richer classes seems to have been largely Romanized, but probably by far the greater part of the country

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

continued to be farmed by the Celtic communities according to their own customs. That agriculture was developed under the Romans is shown by the large quantities of wheat that were exported, but this crop was already widely cultivated before the conquest. It is worth noting that during the first few centuries of the Christian era the climate of Britain must have been considerably warmer than it now is; for instance, large trees grew at high altitudes in the north of Scotland, and there was a large population and a flourishing civilization in the Hebrides.

The Anglo-Saxon invaders swept away, over the greater part of midland and eastern England, all traces of Celtic and Roman institutions and established their own agricultural customs. They lived in large agricultural villages and had large permanent arable fields, divided into long, narrow acre-strips. They used a heavy plough drawn by eight oxen yoked in pairs. Rye was probably their main bread-corn, but they grew also wheat and barley, beans, peas, oats, flax, and some minor crops. The area of Anglo-Saxon field systems extended as far north as Durham and as far west as the Severn Valley. Farther north and west Saxon influences penetrated, but only partially and slowly, and many features of the earlier Celtic agriculture remained. A curious exception within the main zone of Saxon influence is furnished by Kent and the lower Thames valley, where Anglo-Saxon field systems cannot be traced.

Subsequent invaders succeeded in establishing their own agricultural organizations only partially and in small areas—the Norsemen in Shetland, Orkney, Caithness, and to some extent in the Hebrides; the Danes only in East Anglia. The Norman conquest brought changes in the system of land tenure, but none of any consequence in farm practice.

It is possible to form a fairly clear idea of the primitive systems of agriculture in two large areas of Britain; one of these, embracing western Scotland and Ireland, long remained almost untouched by Saxon influences; the other is the almost purely Saxon area already mentioned. The systems had, of course, many features in common. In both cases the business of farming was carried on by communities on a partnership basis. Each cultivator had his own livestock and his own crops. But the pasture land was common at all times, and even arable was subject to common rights except when there was a crop upon it. In both there was co-operation between several farmers in the work of ploughing. In both the shares of the individual cultivators seem to have been originally equal. There were also, however, many important differences.

The Celtic System—The Celtic agricultural township was ordinarily small, embracing typically only two or three hundred acres, and supporting a correspondingly small number of families. Townships of four, six, eight, and twelve families occurred frequently, while those of sixteen and twenty-four were comparatively rare. Five-fold and seven-fold divisions do not seem to have occurred at all. The system

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

pursued was one of shifting cultivation. A given area of the townships land was broken up out of wild grass, etc., and the various arable strips, each corresponding to a day's ploughing, were distributed among the various partners by ballot. After a variable number of years this particular block of land, having been exhausted and rendered foul by repeated cropping with grain, was abandoned to nature and another block was broken up. The plough used was a slight wooden implement with originally only one stilt. In this were yoked, all abreast, four of the small Celtic ponies, the driver walking backwards before them and holding all four halters. In certain districts in Scotland, where the amount of arable land was small, ploughs were not in use, tillage being performed by the cas-chròm, an implement that can be regarded as a kind of common ancestor of both the spade and the plough.

The chief crops were "four-rowed" barley (bere or bigg) and oats. In Scotland there is little doubt that *Avena strigosa* (the bristle-pointed oat) was the only species of oat grown in early times. Wheat may probably have been abandoned with the deterioration of the climate that occurred in early mediæval times. Small areas of flax seem to have been cultivated as far back as records go.

The livestock belonged, mainly at least, to the Neolithic types. The cattle were small, dark coloured, and short horned (*Bos longifrons*); the sheep were of the little, old, tan-faced breed, with soft wool and goat-like horns, and the horses were probably the so-called Celtic ponies (*Equus celticus*). The relative importance of stock and crops doubtless varied according to the nature of the country. In the mountain regions the herds were the chief support of the people, who lived largely on milk, cheese, and butter. In these districts great numbers of goats were kept, as being probably more useful milk animals than sheep; but milk was also obtained from ewes. In the mountain regions, too, it was a usual practice to move all the livestock from the neighbourhood of the permanent homestead to summer pastures at higher altitudes, the attendants being in rough huts or sheilings on the high ground.

The main changes that occurred in this organization up till the time of the agricultural revolution may be briefly summarized. As land became comparatively scarce, particular blocks had to be brought under cultivation after shorter periods of rest, and resort was made to various artificial methods of restoring fertility. The commonest was to surround the block with a temporary wall of turf and to use the enclosure as a night fold for the livestock during the summer season before breaking it up. Again, if the land were of a peaty nature it might be pared and burnt. Another curious practice of considerable antiquity was that of leading stream water on to the area, where this was possible, and irrigating for a season before ploughing out.

A different development of the system, which seems to have been confined to Scotland, was the formation of *infield*. The infield was a comparatively small area in the vicinity of the hamlet which was kept permanently under arable crops—that is to say, oats and bere—

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

which received all the dung that was produced. A certain measure of weed control was obtained by delaying the sowing of the bere crop until very late in the spring. The infield land commonly remained in runrig—that is, in scattered strips—but the strips soon came to be permanently attached to particular holdings, the periodic redistribution being dropped.

The Anglo-Saxon System—The system of farming pursued by the typical community in the midland and eastern area of England has been often and fully described (see Ernle, "English Farming Past and Present"; Venn, "Foundations of Agricultural Economics"). The typical community was a large one, and the area occupied ran frequently to two or three thousand acres. Apart from the small pastures for work oxen, etc., which were situated in the village itself, the land was unenclosed, and consisted of arable, meadow and pasture. The arable open fields were either two or three in number—more usually and in all the more fertile areas three. Each field was divided into long and narrow strips of roughly half an acre or one acre in extent. But because the customary acre was originally a day's ploughing, the actual measured area varied according to the nature of the ground. The holding of each cultivator consisted of a number of scattered strips, distributed about equally between the three (or two) fields. The scattering of the holdings appears to have been done with the idea of ensuring to each man a just proportion of good and of poor soil. With the three-field arrangement one field was sown annually with winter corn (rye, wheat, or meslin), another with spring corn (barley, oats, pease, or beans), and the third lay fallow. Under the two-field system one field was cropped while the other lay fallow. The whole of the arable was regarded as common land except when it was under preparation for, or actually carrying, a crop.

The meadows or "ings" were enclosed by means of temporary fences or hurdles in spring. They were divided into approximately equal shares, and the shares were distributed, before hay harvest, by ballot. After the hay crop had been carried the land became common grazing until the following year. The remainder of the land was common on which each group of stock—sheep, geese, cows, oxen, etc.—pastured under the care of a herdsman. The livestock appears to have been of very mixed character, but the sheep were kept mainly for the sake of their wool, and the cattle for labour and for milk. Every writer agrees that the condition of the livestock, especially during winter, was miserable. None was fit for slaughter except during the autumn. Diseases, especially liver rot, took a very heavy toll.

The plough team, in theory at least, consisted of eight oxen, each of four partners supplying a pair. Sometimes all eight were actually used, but in other cases it would appear that two pairs were worked while the others rested.

Under the Norman domination the greater number of cultivators were bondmen, *i.e.*, they were astricted to the ground and rendered services to the lord of the manor, principally in the form of work on

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

the lord's demesne. In course of time, however, the tenures became very mixed. Some cultivators acquired the freehold of their land; great numbers, especially after the Black Death, were permitted to commute their services for a fixed annual money payment which, with the progressive decline in the value of money, became almost a nominal sum. Thus arose a very large class of copyholders. Other members of the community possessing no arable holding were allowed to acquire common rights. Hence the great difficulties that were experienced in enclosing and redistributing the land in order to form modern consolidated farms.

Until enclosure took place there was little opportunity for progress or change in farming methods. In a few cases a two-field system was converted into a four-field, the area of fallow being thus reduced to one-fourth, and the rotation becoming winter corn—beans or pease—spring corn—fallow. Such developments, however, were rare.

The Systems of Other Areas—It is difficult to generalize about the early systems of the remaining districts. In the East of Scotland the organization remained fundamentally Celtic, although the English custom of reckoning holdings by virgates and ox gangs was introduced. The "long" plough, with its large team of oxen, was adopted throughout the whole area as far north as Easter Ross. In Northumberland and Berwickshire there was a marked tendency towards the large agricultural villages that characterized the Anglo-Saxon area, but there is no trace of any two- or three-field system. Devon and Cornwall, Wales, Lancashire, and the north-western counties were predominantly Celtic in their institutions, while Somerset and the counties of the Welsh border were mixed. East Anglia developed a system peculiar to itself.

The Enclosure Movement—The redistribution of the land, so as to form compact holdings under the control of individual farmers, was a process that was spread over many centuries and is still not quite complete.* It is easy to understand that in the north and west the task was comparatively easy of accomplishment. The townships were small, and readily convertible into modern farms of convenient size. The persons having rights in a particular township were commonly few, and agreement was usually not difficult to secure. Broadly speaking, these areas were enclosed about as soon as conditions really called for the change. Wherever the land was good enough to warrant the expense of enclosure, or wherever livestock husbandry became specially important, enclosures were made very early. This applied, for example, to Devonshire. Moors and the poorer commons were mostly left until the late eighteenth and early nineteenth centuries, when the high price of corn made their enclosure and reclamation a reasonable business speculation. On the other hand, it was generally impossible to secure enclosure by agreement in the case of the large open-field manors of the Midlands, and there

* Laxton, in Nottinghamshire, is one of the remaining examples of the open-field system.

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

most of the task still remained to be done after the middle of the eighteenth century. Even then most of the enclosures were accomplished only with the help of the Legislature in the form of private Acts of Parliament.

The enclosures of Tudor times, which raised a prolonged and violent storm of protest, were made chiefly by the large landowners with the object of converting arable land into sheep walks. At the time in question wool was the chief exportable commodity that England produced; English wools, especially the long lustre wools, were in great demand for the manufactures of the low countries. The upper classes were beginning to demand imported manufactured goods and luxuries, and they looked to their sheep farms to produce a cash income. Despite the loud outcry it is clear that the Tudor enclosures were on a comparatively small scale, and that it was chiefly the poorer and more worn-out arable lands that were concerned.

The second great period of active enclosure, corresponding roughly to the reign of George III., was a time of rapidly increasing population and of rapid progress in manufactures and trade. The motive underlying the enclosures was that of increasing the home output of food. That this was accomplished by a change over from the old open-field husbandry to a rational system of mixed farming there can be no question. The unfortunate consequence of the movement was the creation of a large class of landless labourers who during the early years of the nineteenth century sank into a very miserable condition, with neither adequate wages nor any prospect of advancement in life. (For a full account of this subject see Curtler, "The Enclosure and Redistribution of our Land," Oxford University Press.)

The New Crops—Among the many notable changes that occurred during the eighteenth century probably the most important was the general introduction of the new crops—clover and sown grasses, turnips, and latterly swedes, and the potato. The regular use of clover in the rotation produced, as might be expected, a marked improvement in the yields of other crops, for under the old system the nitrogen supply must often have been the limiting factor in crop growth. Under the Norfolk system of arable farming red clover was generally sown, but in the north and west mixtures of rye-grass, red and white clover, trefoil and rib grass, were employed. Such seedings, although they have been greatly improved upon in the past hundred years, were good enough to place the old system of alternate husbandry on a far better basis. Not only did the new leys carry more stock than the old tumbledown pastures, but they restored fertility far more rapidly and enabled the land to carry much better crops when it came to be broken up.

Turnip cultivation made but slow progress, except in the eastern counties, until near the end of the century. Enthusiastic improvers frequently blamed the plain farmer for his reluctance to grow this crop, but it must be remembered that a market for meat and milk was growing up but slowly, and was easily over-supplied. What

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

the towns were demanding were increasing supplies of wheat; it was only the well-to-do citizens who had come to regard meat as anything but a luxury. Even as late as the seventeen-nineties, when wheat stood at sixty or seventy shillings a quarter, meat could be bought in provincial towns at fourpence or fivepence a pound. The main inducement to take up root growing was the value, to the corn crops, of the dung from the winter-fed stock.

Norfolk, partly owing to soil and climatic conditions and partly because of its proximity to the London meat market, led in the matter of the turnip and clover husbandry. Potatoes, on the other hand, were most valued in the poorer districts, where the people were living perilously near starvation point. Ireland, Scotland, and Lancashire began by 1750 or 1760 to regard the crop as an important source of food, but with the transport facilities then available it could be grown only for local consumption. The development of large-scale commercial culture, except in suburban areas, had to await the coming of the railways.

The Great Improvers—Possibly because of the growing national importance of the problem of food supply, a large number of men of intellect and education began during the eighteenth century to devote themselves to agriculture. Scientific men began to think about the problems of plant and animal nutrition, men of leisure interested themselves in experiments, and the large landowners began to vie with each other in the improvement of their estates. The scanty stream of agricultural literature gradually increased throughout the century until it reached dimensions that have never been equalled before or since. It is true that many of the books, written often by men of inadequate practical experience, and before there was any real scientific basis for theory, contain a good deal of foolishness; yet they contain, too, many records of acute observation and many theoretical speculations that were not so wide of the mark. For example, Dr. Home's "Principles of Agriculture and Vegetation" (1757) and the Earl of Dundonald's "Treatise showing the Intimate Connection that Subsists between Agriculture and Chemistry" (1795) laid a real foundation for the science of plant nutrition.

Among the great improvers it is the custom to give pride of place to Jethro Tull (1674-1741), who published his famous "Horse-Hoeing Husbandry" in 1733. It must indeed be said that Tull's notions of plant nutrition were not only wrong, but were rather absurd even for the time in which he lived. He believed that the food of plants consisted of small, solid, soil particles; that the function of tillage was to produce particles small enough for the plant roots to take them in; and that manures were of value only in the sense that they were partial substitutes for tillage, when the latter was inadequately carried out. Tull's practice—of sowing crops in widely separated rows, in order to allow very thorough summer cultivation—was wrong as applied to wheat and the other cereals. It proved to be right as applied to the new root and potato crops, but for reasons other than those

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

which Tull advanced; summer tillage was a substitute, not, as he thought, for manures, but for bare fallows. His theories, however, aroused widespread interest and led to many new experiments; moreover, the invention of a workable drill was in itself an important service. Among the great improving landlords of the earlier part of the century Lord Townshend (1674-1738) was outstanding. Although he was not the originator of the modern rotation, in the form of the Norfolk four-course, he provided the first big demonstration of its value to the light land farmer. In Scotland a group of influential men formed themselves into a "Society for the Improvement in the Knowledge of Agriculture," and greatly assisted the introduction of the best Norfolk practice.

Following the band of pioneers in the art of arable farming came another in that of stock breeding—Robert Bakewell (1725-95) with his Leicester sheep and Longhorn cattle, Benjamin Tomkins (1714-89) with his Herefords, and later the Colling brothers (Shorthorns), John Ellman (Southdowns) and a host of others. In the old days of open-field farming and common grazing, the improvement of livestock was a hopeless undertaking, for disease and starvation left the breeder but little choice of material. But with enclosures, winter food, and the beginnings of a market for meat, a new opportunity presented itself. Bakewell was the first to see clearly that the old slow-growing and hard-feeding types of cattle and sheep, bred, the one for milk and labour and the other for wool, required to be remodelled for the new conditions; and during the course of his life he not only discovered all the important principles of stock breeding, but evolved new types of both cattle and sheep. His plan was, briefly, to search out the best possible foundation animals, to apply a breeding test to his sires, and to mate together closely related animals in order to secure fixity of type.

By far the greatest agricultural writer of the period, and indeed our greatest of all time, was Arthur Young (1741-1820). He published an enormous number of volumes—general works, tours, surveys, etc., and a "Farmers' Calendar" that ran through a dozen editions during his life and almost as many more after his death. He also edited from 1784 till 1815 the "Annals of Agriculture," and himself contributed to it innumerable articles. Young was Secretary, and Sir John Sinclair President, of the first Board of Agriculture, and between them they organized the great task of surveying, county by county, the farming of Great Britain. The "General Views of the Agriculture" of the various counties, published between 1793 and 1813, contain a great mass of information, and may well repay study even to-day. Young's works were of great value in spreading the knowledge of the best farm practice and in stimulating enclosures, the cultivation of the new crops, and the improvement of livestock.

Land reclamation went forward at a rapid and increasing pace between 1790 and 1813. Many of the more fertile areas, including a considerable part of the Fens, had, of course, been dealt with in the preceding two or three centuries. But never had there been

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—
such a period of draining, liming, and building. Coke of Holkham (1754-1842) set a notable example on his poor, sandy land in Norfolk, applying marl in great quantities, maintaining large numbers of live-stock, and reletting his farms, after the process of improvement, to enlightened tenants. It is said that between 1776, when he began, and 1816, the rent roll of his estates rose from £2,200 to £20,000.

Apart from Jethro Tull's drill, which had been improved by subsequent makers, a notable addition to the machinery of the farm was the thrashing machine, invented by Meikle in 1787. Of several improved types of plough the best known was that of Small, introduced about 1780.

1814-36—The severe fall in prices that occurred at the end of the Napoleonic wars caused an acute agricultural crisis; tenants found themselves with farms greatly over-rented under the changed conditions, and most had long leases; many occupying owners had borrowed money to carry out improvements, and found themselves overburdened with debt. Many ambitious schemes of improvement came to sudden ends. The history of farming between 1814 and 1836 is little else but a gloomy tale of bankrupt tenants, foreclosed mortgages, and destitute labourers,

1836-72—But the industrial population was growing with great rapidity, and after 1836 prices began to pick up. The years 1845-47 were indeed full of trouble, for close upon the collapse of the great railway boom came the calamity of the Potato Blight, which caused the famine in Ireland, and led to the repeal of the Corn Laws. The writings of this period are full of the gloomiest forebodings. Yet the fact was that the industry was soon to enter upon a quarter of a century of solid prosperity. The price level rose, owing to increasing supplies of gold, and when the import barriers were removed it was found that there had been no great pressure of supplies behind them.

The most important technical advance of the period 1837-72 was the introduction of artificial manures. It is true that lime and small quantities of bones had been used before this time, but the main principle of good farming had been to conserve fertility by keeping a large head of stock, and by returning to the soil a large proportion of its produce. The publication in 1840 of a translation of Liebig's "Chemistry in its Application to Agriculture and Physiology" opened up new possibilities. Liebig indeed was wrong on the nitrogen question, but his broad idea of determining the composition of the plant ash, and of ensuring adequate supplies of the elements composing it, was bound to prove fertile of results. The effects obtained from applications of Peruvian guano provided a striking illustration of the value of concentrated manures, and imports of this substance rose from 1,700 tons to 220,000 tons between 1841 and 1847. Liebig himself had suggested the treatment of bones with sulphuric acid, and in 1842 Lawes obtained a patent for the superphosphate process, applying it both to bones and to coprolites. In the following year he

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

founded a well-equipped experiment station at Rothamsted and secured the co-operation of Gilbert in the direction of its work. Thus began a collaboration that was to last for fifty-seven years, and was to build a great part of the structure of modern agricultural science.

The introduction of reaping machinery was the most important innovation on the engineering side. The first workable reaper had indeed been invented by Patrick Bell in 1828, but it was not until after 1850 that any regular manufacture was begun. In this country, what was practically Bell's machine was produced by Crosskill of Beverley, while a different model was manufactured by McCormick in the United States. From 1830 till 1870 a good deal of effort was spent on the problem of steam tillage, and the opinion was widely held that steam power was destined to revolutionize farming, as it had already begun to revolutionize transport and manufactures. The chief credit for such success as was actually achieved belongs to the firm of Fowler of Leeds, who brought out their first set of tackle in 1854. Eventually, however, it became clear that any wholesale replacement of farm horses by heavy and powerful steam engines was impracticable. Indirectly, of course, the introduction of steam power had an important influence on agriculture, for the railways opened up new markets to many of the remoter country districts, and to some extent deprived the suburban farmer of his monopoly in the production of bulky and perishable articles.

There was still at this time a large area of wet land that had never been drained, and after the long depression there was much more that needed redraining. Smith of Deanston, in Perthshire, published his "Remarks on Thorough Draining" in 1831, when he had already demonstrated in practice the principles which he enunciated. (See Draining.) Unfortunately a great deal of land was drained not according to his plan, but according to the recommendations of Josiah Parkes, who insisted that all covered drains should be 4 ft. deep. Many of the old Government grant drains, buried at this depth in the clays of Essex and the Midlands, have drawn scarcely a drop of water in the seventy or eighty years of their existence. Up till 1850 a great variety of materials was used in draining, but in 1845 Scragg patented a machine for making circular tiles, and these gradually displaced everything else.

A pioneer in quite another direction who deserves to be remembered was the East Lothian farmer Patrick Shirreff, who between 1856 and 1875 produced a new range of varieties of oats and of wheat. The interesting point about Shirreff's method is that he applied the principle of pure line selection half a century before Johannsen formed the scientific conception of the pure line. (See Mendelism.)

Animal improvement continued to make rapid progress, and the work was encouraged by a growing overseas demand for high-class livestock. As generally happens in good times, the later sixties and early seventies saw an extraordinary boom in certain relatively scarce strains—Bates Shorthorns in particular. Livestock shows played an important part in the improvement of stock, partly because

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

they set up recognized standards and partly because they greatly helped to educate the more backward farmers. The Royal Agricultural Society was formed in 1838, and held its first show in 1839. Smithfield and the Highland Show began earlier, the former in 1799 and the latter in 1822.

Economic Conditions, 1872-1930—In the late seventies the prosperity of home agriculture began to wane. After 1870, indeed, it rested upon rather an unsound foundation. The Franco-Prussian war and the expansion of credit caused a rise in prices, but there was the inevitable reaction, ending in the financial crisis and the bank failures of 1878. A run of poor seasons culminated in wet and cheerless 1879, when the average yield of wheat fell to 16 bushels an acre, and the rot killed three million sheep. There was no compensation for these calamities in the form of enhanced prices, for the flood of imported corn, that had been feared in 1846, arrived now in good earnest. Cheap ocean transport was now an accomplished thing, railways were rapidly crawling west across the American prairie, and the invention of the string binder in 1878 removed the last obstacle to the mass production of wheat on the rich virgin soil. Corn imports continued to increase and prices to fall until 1893 or 1894, and values remained for a further dozen years at a level which met costs of production only on the better corn land. Only about 1906 did a slow recovery begin. Prices of livestock products fell also, but not so disastrously, and many farmers saved themselves by turning from tillage to grass. Numbers of the poorer and heavier arable farms fell derelict, and others were kept in cultivation only by letting them at nominal rents, or at no rents at all. In some districts there was a complete change in the system of farming, as well as in the personnel of the farming community. Corn growing gave place to dairying, and the fox-hunting farmers made way for men who lived in their kitchens and worked from daylight till dark.

The Great War (1914-18) and its aftermath brought conditions of great difficulty for the farmer. Inflation of the currency caused a rise in prices of agricultural as well as of other commodities, and a great falling off in imports threatened to raise food prices to famine level. It was clear by 1916 that strenuous efforts would be required in order to prevent actual starvation. These measures took three forms. On the one hand the Government conducted a campaign to increase the home output of corn, and local committees were given powers to compel the ploughing out of grass land and the increase in the cereal acreage. Assistance in the form of supplies of supplementary labour, tractors, etc., was provided as far as possible. These measures were so far successful that two million acres were added to the arable area, and the home production of wheat was raised in 1918 to 58 per cent. above the average of the pre-war years. At the same time the prices of all the more important agricultural commodities were controlled, livestock, for instance, being graded and valued on a live weight basis, while a flat rate was fixed for wheat. The quartern

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

loaf was stabilized at ninepence, partly by a subsidy on imported wheat and partly at the expense of the home farmer. Supplies of fertilizers and feeding stuffs were controlled. Finally, most of the important foodstuffs other than bread were rationed. The end of the war found farmers with considerable paper profits, some invested reserves, and a good deal of land, owing to overcropping with cereals and inadequate tillage and manuring, in a bad state of cultivation.

The two post-war years were exceedingly prosperous for the farmer. Prices mostly rose when control was removed, while wages, and still more rents, lagged behind. In 1920 the agricultural index figure rose to 189 per cent. above the level of 1911-13; that is to say, for every twenty shillings of pre-war gross income the farmer was now receiving nearly fifty-eight shillings. In 1920 Government passed the Agriculture Act, Part I. of which guaranteed minimum prices for wheat and oats, the actual figures to be determined from year to year according to costs of production. The basal prices, for the standard year 1919, were 68s. per quarter for wheat and 46s. for oats.

In 1921, however, a disastrous fall in prices began and was progressive until 1923. Wheat dropped in three years from 80s. 10d. to 42s. 2d.; barley from 89s. 5d. to 29s. 1d.; oats from 56s. 10d. to 26s. 8d. At this time costs were still high, and it has been estimated that in 1923 the purchasing power of a sack of wheat was little more than a third of what it had been before the war. The losses that fell to be met by the taxpayer during the first year of the operation of the Agriculture Act (they amounted to £18,000,000) were so alarming that the policy of guaranteed prices was at once abandoned and the farmer was left to bear his own burdens.

In 1917, as part of the Corn Production Act, a Wages Board had been established for agriculture, but the principle of fixing minimum wages was temporarily abandoned with the repeal of the Agriculture Act. In 1924, however, a Central Wages Tribunal, with County Wages Boards, was established for England and Wales. The effect of this was to maintain the wages of agricultural labourers, up till 1930, at approximately 75 per cent. above the pre-war level. If allowances be made for shorter hours and standard overtime rates, the cost of labour to the farmer was approximately double its pre-war level. A further fall in farm prices, due partly perhaps to over-production, but mainly to the return of one country after another to the gold standard, brought the agricultural index figure by 1930 to only 40 per cent. above the basal pre-war period. These conditions led to acute distress among tenants and occupying owners, and the arable acreage fell below the pre-war level. Only in one or two departments—milk production and mountain sheep farming—did the years 1923-30 produce anything like an adequate profit to the farmer.

Technical Progress since 1880—That the growth of technical knowledge of his business does not necessarily bring increasing prosperity to the producer is well illustrated by the history of agriculture during the past half-century. At no other period in the history of the

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

world has agricultural science made as rapid progress. The farmer's resources in the form of manures, feeding stuffs, crop varieties, implements, etc., have enormously increased, and his costs of production, in terms of human labour, have fallen greatly. But the resulting benefit has been distributed entirely between the consumer, in the form of lower prices, and the labourer, in the form of higher wages. The landowner and the farmer have both suffered a diminution of real income.

The technical advances referred to have been so many that nothing but the briefest catalogue can here be attempted.

The most important manures made available during the period have been potash salts, basic slag, and the various synthetic nitrogen compounds obtained from the atmosphere.

Previous to 1860 small supplies of potash were obtained from kelp and wood ashes, but there was no considerable use of these as manures. In that year the mines at Stassfurt in Germany began to be exploited, and their output had risen to about 100,000 tons (reckoned as pure potash) in 1880. In 1906 this figure had increased to 700,000, and in 1928, with the additional supplies from Alsace, to 2,400,000 tons. Cheap supplies of potash have greatly increased the output on the lighter classes of soils of this country, and have materially lowered the potato growers' costs. The production of basic slag (*q.v.*) as a by-product of the steel industry began in 1879 with the invention by Thomas of an improved process for the manufacture of Bessemer steel from phosphoretic pig iron. Attempts to utilize the material as a manure gave unsatisfactory results until it was discovered that very fine grinding was necessary in order to improve its availability. The classical experiments by Somerville at Cockle Park first demonstrated to the farmer the great benefits to be derived from its use on poor grass land. Slag is still perhaps the most reliable and most widely used manure for pastures. The first successful attempt on a commercial scale to synthesize nitrogenous manures from the air was the manufacture of calcium cyanamide (*q.v.*), which began in 1903. The nitrate of lime process followed soon after, while the manufacture of synthetic ammonia was placed on a commercial basis by German chemists during the war. As a consequence of these developments the world supply of combined nitrogen has been nearly trebled, and the price of the standard manures, like sulphate of ammonia, has been reduced by several pounds per ton.

In plant improvement the Mendelian discovery and the pure line theory of Johannsen have proved very fertile of results. The old standard varieties of wheat, oats, and barley have been largely replaced during the present century by new and better sorts, some bred by home research departments, some of them of Swedish origin, and some produced by British commercial firms. More adequate arrangements have also been made for maintaining the purity of varieties and for testing novelties against established types. The production of potato seedlings has been systematized, and with a general understanding of the problem of Virus Diseases it has become pos-

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—
sible to maintain the vigour and to lengthen the life of the new varieties.

Apart from the improvement of grass land by manuring, which has materially increased the stock-carrying capacity of many farms, great progress has been made in the seeds mixtures employed in the formation of temporary and permanent pastures. The discovery of the value of wild white clover (*q.v.*), especially for long leys, was one of first-rate importance, and has been followed by the isolation of hardy indigenous strains of other pasture plants.

A number of the more important plant diseases and pests have been, to a greater or less extent, brought under control. Bunt and Smut of wheat, for example, which in the past frequently caused extensive damage, are now easily preventable. (See Seed, Transmission of Disease by.)
The Potato Blight (see Potato, Diseases of) still causes damage in certain seasons, but on nothing like the scale of the earlier attacks. Effective insecticides and fungicides (see Insecticides and Fungicides) have been produced for dealing with the pests of the more valuable crops like fruit and hops, but their use on ordinary field crops is still limited by their cost.

Perhaps the most notable step in connection with animal improvement was the inauguration of official milk recording, due mainly to the influence of John Speir, in 1906. The movement has since spread to practically every county in Britain. In the meat-producing breeds there has been a marked improvement in the rate of maturity, induced partly by a change in the public taste and made possible in part by the larger available supplies of concentrated feeding stuffs.

The researches of Wolff and Kellner in Germany, of Armsby in the United States, of the Scandinavian school of investigators, and of Lawes and Gilbert, Wood, and others in this country have placed the rationing of stock on a very sound basis and have made possible a considerable improvement in the efficiency of animal production. (See Foods and Feeding, Scientific Aspects of.)

Several of the once ruinous diseases of livestock have been entirely stamped out. There has been no outbreak of rinderpest in Britain since 1877, and none of pleuro-pneumonia since 1898. The control of Foot-and-Mouth disease has attained a considerable measure of success, and the farmer has been given valuable weapons against liver rot, once the most fearsome of all the stock farmer's enemies.

Up till the middle of last century the chief improvements in farm implements and machinery originated in Britain. Since that time, however, it has fallen to the new countries, particularly the United States and Australia, to produce most of the notable innovations in the way of labour-saving machinery. Indeed, it was only natural to expect this; for it is in these countries that the problems of labour shortage and high wages have pressed most closely on the farmer. To the United States we owe the string binder, much of our modern hay-making machinery, and the broad idea of using replaceable steel

AGRICULTURE, BRITISH, HISTORY OF (*Continued*)—

working parts on many tillage implements. To Australia belongs the chief credit for the Combine Harvester, whose utility for British conditions is, however, still doubtful. In the development of the milking machine and the agricultural tractor this country, however, played a not unimportant part.

Despite the activities of national organization societies and very considerable help from Government, the marketing of agricultural produce and co-operation generally have remained in a relatively backward condition in Britain. In England, collective bargaining through the medium of the Farmers' Union has met with success in the case of milk. In Scotland the problem appears to have been satisfactorily met by the formation of a central milk agency. There are cases of successful co-operative purchasing societies, but there are more examples of failure than of success in co-operative dairies, bacon factories, egg-marketing societies, and the like. It has, of course, to be admitted that with scattered consumption as well as scattered production the problem of organized marketing in this country is one of rather special difficulty. Marketing under the National Mark Scheme of the Ministry of Agriculture is making satisfactory progress at the time of writing. (See Marketing.) J. A. S. W.

AGRICULTURE, BRITISH ISLES—Crop and Certain Other Statistics— The various accounts of different home-grown crops appearing in these pages give a general idea of the systems of agriculture found in various parts of the British Isles to-day, whilst in most cases an attempt has been made to indicate the relative importance of the crop in the rural economy of the United Kingdom. The following is an amplification of the statistics relating to crops stated in relation to the industry as a whole, together with a short statement of the changes that have occurred in recent years. To this is added a statement of the value of the agricultural output.

The information presented below has been obtained from "The Agricultural Output of England and Wales, 1925," and similar publications for Scotland and Northern Ireland, which are reports of statistical enquiries made in connection with the Census of Production Act, 1906, relating to all kinds of agricultural produce and to the agricultural industry generally, together with a brief survey of agricultural statistics up to 1925.

Changes in the Area of Cultivated Land, i.e. of Arable Land and Permanent Pasture, England and Wales—The area of England and Wales, inclusive of inland water and tidal land, is 37,136,000 acres, and of this 25,755,000 acres were returned to the Ministry of Agriculture in 1925 as being under cultivation either as arable land or permanent pasture, in holdings of over 1 acre. Along with this there was a total area of 3,920,000 acres described as rough grazing, and 1,104,000 acres of common land and mountain heath, the whole making a total of 30,780,000 acres accounted for in the agricultural returns to the Ministry.

AGRICULTURE, BRITISH ISLES (*Continued*)—

In the period 1871-75 the total cultivated area was 26,565,000 acres, while that of the period 1921-25 was 25,949,000 acres. The following table shows the distribution of the cultivated land between arable and permanent pasture, from 1871 to 1925, together with the areas actually under the plough (tillage) in that period:

Average of Years.	*Acreage (Millions of Acres).*		*Percentage of Area of Cultivated Land.*		*Acreage (Millions of Acres).*		*Percentage of Area of Cultivated Land.*	
	Arable Land.	*Permanent Grass.*	*Arable Land.*	*Permanent Grass.*	*Tillage*	*Permanent Grass and Rotation Grasses.*	*Tillage.*	*Permanent Grass and Rotation Grasses.*
			Per Cent.	Per Cent.			Per Cent.	Per Cent.
1871-75 ..	14·77	11·80	55·6	44·4	11·72	14·85	44·1	55·9
1881-85 ..	13·75	13·84	49·8	50·2	10·83	16·76	39·3	60·7
1891-95 ..	12·68	15·11	45·6	54·4	9·63	18·16	34·7	65·3
1901-05 ..	11·91	15·55	43·4	56·6	8·77	18·69	32·0	68·0
1906-10 ..	11·44	15·90	41·8	58·2	8·64	18·70	31·6	68.4
1911-15 ..	11·13	16·01	41·0	59·0	8·66	18·48	31·9	68·1
1916-20 ..	11·80	15·08	43·9	56·1	9·43	17·45	35·1	64·9
1921-25 ..	11·14	14·81	42·9	57·1	8·63	17·32	33·3	66·7

It will be observed that the areas described as arable land and as permanent pasture in 1871-75 were 55·6 and 44·4 per cent. respectively of the total cultivated area, while in 1921-25 comparable figures were 42·9 and 57·1 per cent. The percentages of the area of cultivated land actually under the plough, and of permanent and rotation grasses, were 44·1 and 55·9 respectively in 1871-75, and 33·3 and 66·7 respectively in 1921-25. The actual changes may be stated as follows: the decline in the tillage area (*i.e.*, the area under the plough) between 1871-75 and 1921-25 was 3,086,000 acres, and during this period the area under permanent grass increased by 3,000,000 acres. Thus, the position to-day is, broadly, that one-third of the total cultivated area is under the plough, and two-thirds are either permanent grass or rotation grasses (see Figs. 1 and 2).

The next aspect to be considered is which of the arable crops have contributed to this change, and the extent to which each individual crop has been affected. The arable area may be divided into two main groups: (*a*) clover and rotation grasses, and (*b*) the land actually ploughed in each year. The total arable area in 1871-75 was 14,766,000 acres, and in 1921-25, 11,144,000 acres, of which totals 3,051,000 acres in 1871-75 and 2,515,000 acres in 1921-25 were in clover and rotation grasses. The land actually under the plough was, therefore,

AGRICULTURE, BRITISH ISLES (*Continued*)—

11,715,000 acres in the former period, and 8,629,000 acres in the latter. The table on p. 50 shows the acreage under various crops in the periods 1871-75 to 1921-25, whilst for purposes of reference

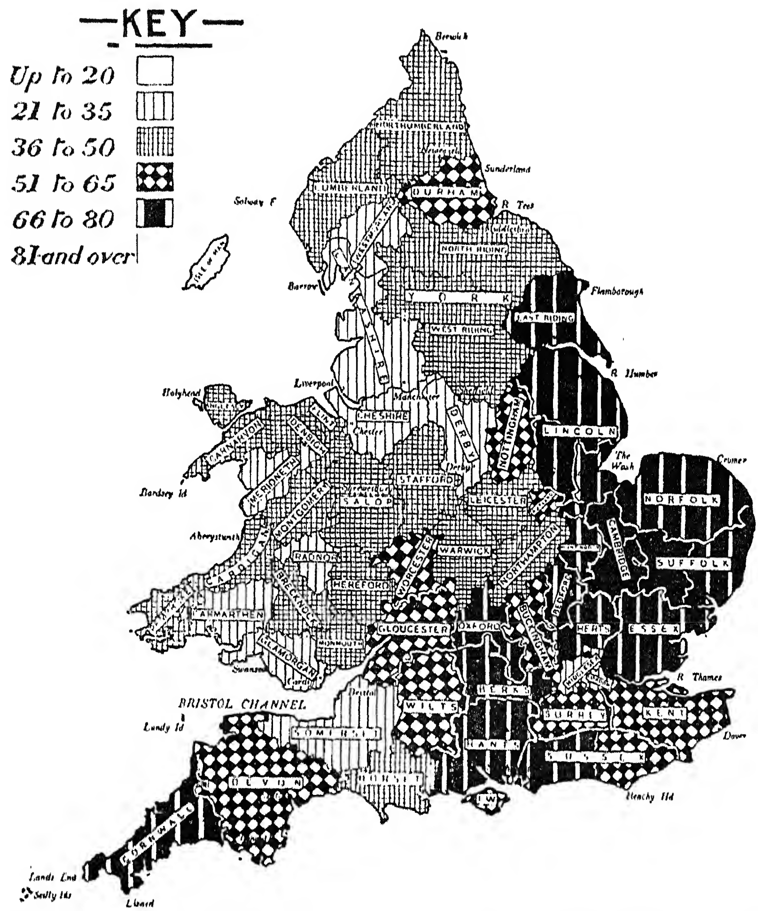


FIG. 1.—SHOWING THE NUMBER OF ACRES OF ARABLE LAND PER 100 ACRES OF CROPS AND GRASS IN 1875.

(From "The Agricultural Output of England and Wales, 1925," Ministry of Agriculture and Fisheries, by permission of H.M. Stationery Office.)

that of 1930 is added. The difference between the first and last period, *i.e.*, between 1871-75 and 1921-25—is shown at the foot.

Taking the cereals as a whole, it will be observed that there is a loss of approximately 3,000,000 acres or 36 per cent. of the area devoted to these crops in fifty years, while on the non-cereal crops the loss

AGRICULTURE, BRITISH ISLES (*Continued*)—
during the same period is 700,000 acres or less than 20 per cent. The heaviest loss amongst the cereals occurs with wheat, which has declined by over 1,650,000 acres or by nearly 50 per cent. in fifty years. Barley

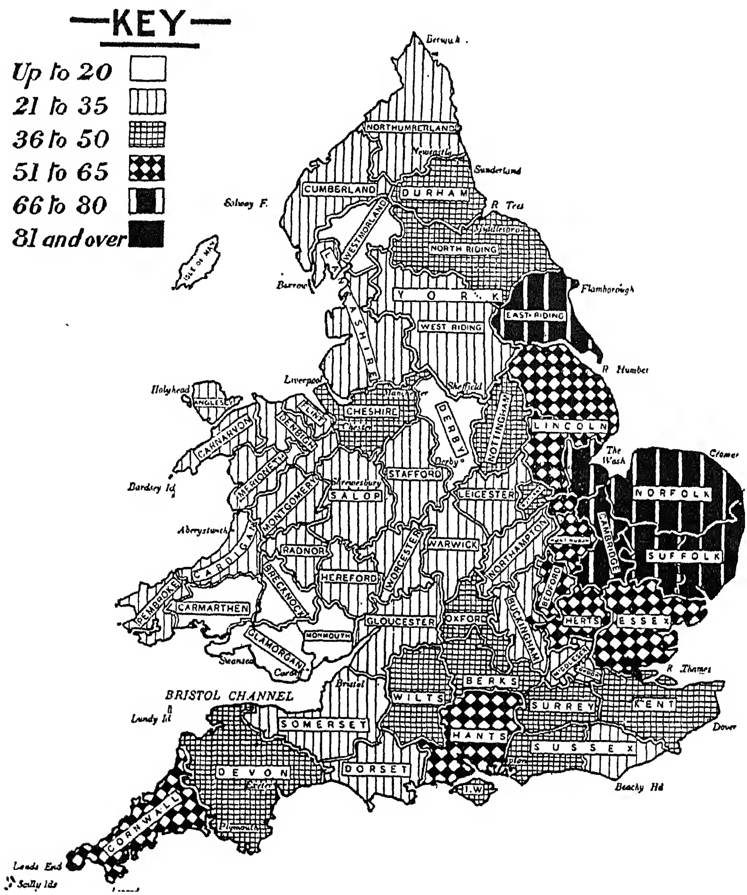


FIG. 2.—SHOWING THE NUMBER OF ACRES OF ARABLE LAND PER 100 ACRES OF CROPS AND GRASS IN 1925.

(From "The Agricultural Output of England and Wales, 1925," Ministry of Agriculture and Fisheries, by permission of H.M. Stationery Office.)

declined by 750,000 acres or 36 per cent., and other "corn," rye, beans, and peas by 300,000 acres or 35 per cent. The acreage under oats increased by 375,000 acres or 23 per cent. in the fifty years.

Amongst crops other than cereals the striking features are the decline in the acreage of turnips and swedes, the increase in the potato

AGRICULTURE, BRITISH ISLES (*Continued*)—
and mangold acreages, the decline in bare fallow, and the increase under miscellaneous crops.

THOUSANDS OF ACRES.

Average of Years.	*Wheat.*	*Barley.*	*Oats.*	*Other Corn.*	*Total Corn Crops.*
1871-75	3,404	2,115	1,664	914	8,097
1881-85	2,646	2,034	1,870	692	7,242
1891-95	1,907	1,881	2,116	530	6,434
1901-05	1,594	1,641	2,134	464	5,833
1906-10	1,679	1,501	2,104	502	5,786
1911-15	1,877	1,435	2,022	498	5,832
1916-20	2,097	1,488	2,392	561	6,538
1921-25	1,746	1,352	2,039	588	5,725
1930..	1,346	1,026	1,773	—	—
Difference	**− 1,658**	**− 763**	**+375**	**− 326**	**− 2,372**

THOUSANDS OF ACRES.

Average of Years.	*Potatoes.*	*Turnips and Swedes.*	*Mangolds.*	*Bare Fallow.*	*Miscellaneous Crops.*	*Total (excluding Corn).*
1871-75	382	1,625	338	601	673	3,619
1881-85	388	1,538	337	711	617	3,591
1991-95	390	1,460	349	442	557	3,198
1901-05	444	1,160	406	347	584	2,941
1906-10	418	1,121	439	300	579	2,857
1911-15	452	1,046	440	327	560	2,825
1916-20	518	959	390	481	541	2,889
1921-25	506	843	390	433	732	2,904
1930	423	671	288	205	—	—
Difference	**+124**	**− 782**	**+52**	**− 168**	**+59**	**− 715**

Scotland—In Scotland the total area of land under crops increased in the fifty-year period 1871-75 to 1921-25. As in England and Wales, the area of permanent grass has increased, and the arable area has decreased. Thus, whilst the area of arable land was 76·2 per cent. and the permanent grass 23·8 per cent. of the total cultivated area in 1871-75, the corresponding figures for the period 1921-25 were 69·9 and 30·1 per cent., respectively. If the rotation grass area is added to that of the permanent grass, then the relation of the land under the plough to that under grass is 46·9 to 53·1 per cent. in 1871-75 and 38·1 to 61·9 per cent. in 1921-25.

The changes in the area of individual crops resulting from the contraction of the area under the plough are shown in the two following tables, the first of which gives the actual area under each crop, and the

AGRICULTURE, BRITISH ISLES (*Continued*)—

second the percentage that that area forms of the tillage area. For purposes of reference the acreages for 1930 are included in the first table.

THOUSANDS OF ACRES.

Average of Years.	*Wheat.*	*Barley.*	*Oats.*	*Total Grain Crops.*	*Turnips and Swedes.*	*Potatoes.*	*Other Crops and Bare Fallow.*	*Total (excluding Grain).*
1871-75 ..	123	252	1,007	1,382	504	168	84	756
1876-80 ..	77	268	1,025	1,370	499	170	76	745
1881-85 ..	69	249	1,044	1,362	489	168	79	736
1886-90 ..	59	218	1,034	1,311	482	151	69	702
1891-95 ..	48	216	1,008	1,272	480	136	60	676
1896-1900	48	234	968	1,250	470	127	61	658
1901-5 ..	42	218	965	1,225	454	135	60	649
1906-10 ..	49	203	952	1,204	444	140	60	644
1911-15 ..	64	181	952	1,197	432	148	55	635
1916-20 ..	67	172	1,084	1,323	415	153	57	625
1921-25 ..	58	158	970	1,186	405	146	59	610
1926-30 ..	57	112	893	1,062	378	140	58	576
1930	54	107	862	1,023	373	123	54	550
Difference	**– 65**	**– 94**	**– 37**	**– 196**	**– 99**	**– 22**	**– 25**	**– 146**

PERCENTAGES OF TILLAGE AREA.

Average of Years.	*Wheat.*	*Barley.*	*Oats.*	*Total Grain Crops.*	*Turnips and Swedes.*	*Potatoes.*	*Other Crops and Bare Fallow.*	*Total (excluding Grain).*
1871-75 ..	5·8	11·8	47·0	64·6	23·6	7·9	3·9	35·4
1876-80 ..	3·6	12·7	48·5	64·8	23·6	8·0	3·6	35·2
1881-85 ..	3·3	11·9	49·7	64·9	23·3	8·0	3·8	35·1
1886-90 ..	2·9	10·8	51·4	65·1	24·0	7·5	3·4	34·9
1891-95 ..	2·5	11·1	51·7	65·3	24·6	7·0	3·1	34·7
1896-1900	2·5	12·3	50·7	65·5	24·6	6·7	3·2	34·5
1901-05 ..	2·3	11·6	51·5	65·4	24·2	7·2	3·2	34·6
1906-10 ..	2·7	11·0	51·5	65·2	24·0	7·6	3·2	34·8
1911-15 ..	3·5	9·9	51·9	65·3	23·6	8·1	3·0	34·7
1916-20 ..	3·4	8·8	55·7	67·9	21·3	7·9	2·9	32·1
1921-25 ..	3·2	8·8	54·0	66·0	22·6	8·1	3·3	34·0
1926-30 ..	3·5	6·8	54·6	64·9	23·1	8·5	3·5	35·1
1930	3·4	6·8	54·8	65·0	23·7	7·8	3·5	35·0
Difference	**– 2·6**	**– 3·0**	**+7·0**	**+1·4**	**– 1·0**	**+0·2**	**– 0·6**	**– 1·4**

It will be noted that the distribution between grain crops, on the one hand, and root, fallow, and other crops is remarkably constant, but shows a slight increase in favour of the former.

AGRICULTURE, BRITISH ISLES (*Continued*)—

Both wheat and barley exhibit large decreases in acreage; a decrease is found in oats also, but to a less serious extent, and this crop now occupies a larger proportion of the tillage area than it did in 1871-75.

Turnips, swedes, and potatoes follow a similar course to wheat and barley, but the proportion they bear to the tillage area is only slightly changed in the fifty years.

Northern Ireland—The statistics presented under the Census of Production for Northern Ireland, "The Agricultural Output of Northern Ireland, 1925," date back to the year 1847.

The following table shows the changes that have taken place in the division of the total cultivated area:

Period.	*Ploughed Land.**	*Hay.*	*Pasture.*
	Acres.	Acres.	Acres.
1847-56	1,064,104	192,820	1,383,397†
1857-66	1,097,602	254,343	1,353,507
1867-76	994,740	323,512	1,430,203
1877-86	880,142	352,425	1,450,603
1887-96	799,704	412,669	1,450,284
1897-1906	699,002	422,240	1,543,864
1907-16	648,347	449,492	1,412,887
1917-26	668,623	465,243	1,390,854‡
1927-30	—	465,061	—

Here, as in the divisions of the United Kingdom dealt with previously, there is a large decline in the ploughed land, but in this case there is a significant increase in the area devoted to hay, and only a small increase in the area of pasture.

The acreages under crops are given in the following table:

Period.	*Wheat.*	*Oats.*	*Total Corn Crops.*	*Potatoes.*	*Turnips.*	*Mangolds.*	*Total Root and Green Crops.*	*Flax.*	*Fruit.*
	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.	Acres.
1847-56 ..	68,864	607,920	717,698	191,720	73,028	3,230	283,550	62,856	
1857-66 ..	63,426	558,307	636,954	259,887	62,807	2,594	339,403	121,244	Not
1867-76 ..	51,348	495,285	556,108	241,071	69,348	2,464	328,908	109,724	available
1877-86 ..	31,661	447,044	487,889	213,920	70,003	4,079	303,985	88,268	prior to
1887-96 ..	19,024	411,728	437,186	203,157	71,730	3,603	292,018	70,501	1906.
1897-06 ..	12,557	379,030	397,230	179,157	71,690	4,544	265,443	36,329	
1907-16 ..	9,076	349,362	363,602	167,207	59,899	2,879	238,645	46,100	7,199
1917-26 ..	9,221	371,256	384,408	168,351	51,480	1,943	227,316	56,900	9,873
1927-30 ..	4,741	309,409	317,704	149,186	41,772	1,251	196,749	31,500	8,720

The decline in the areas devoted to the two cereal crops is very significant: wheat has practically ceased to play a part of commercial importance, and the oat area has declined by no less than 236,000 acres.

Potatoes and turnips share in the general decline, but not to a serious

* Exclusive of fruit. † 1852-56. ‡ 1923-27.

AGRICULTURE, BRITISH ISLES (*Continued*)—
extent; flax, however, appears to be very gradually assuming a position of smaller agricultural importance. (See Flax.)

The statistics gathered by the Ministries of Agriculture of England and Wales, Scotland, and Northern Ireland under the Census of Production, and contained in separate Reports on Agricultural Output, 1925, are carried a step further in " The Agricultural Output and the Food Supplies of Great Britain, 1929 " (*Min. of. Agric. and Fish.*).

In this publication the value of the agricultural output is summarized from the information given in the three individual Reports, and a grand total of values is arrived at by the summation of values under the following divisions and subdivisions:

In the following table, taken from the same Report, the percentage of value of gross output in each principal group is shown for the different parts of the United Kingdom:

THE AGRICULTURAL OUTPUT OF THE UNITED KINGDOM IN 1925.

	Gross Value.	Percentage of Total.
Live Stock and Live Stock Products :	£	
Live Stock	108,790,000	38·0
Milk and Dairy Produce	69,419,000	24·2
Poultry and Eggs (including feathers)	20,715,000	7·2
Wool	4,518,500	1·5
Total	203,082,500	70·9
Farm Crops :		
Grain	28,336,000	9·9
Potatoes	16,210,000	5·7
Other crops	12,953,000	4·5
Total	57,499,000	20·1
Fruit, Vegetables, etc. :		
Fruit	10,176,100	3·5
Vegetables	8,943,775	3·1
Flowers, Nursery Stock, and Glass-house produce	6,525,000	2·3
Honey	201,140	0·1
Total	25,846,015	9·0
Gross Value of Agricultural Output	**286,427,515**	100·0

It is unnecessary to dilate on the preponderating importance of live stock and live stock products, for the figures speak for themselves. But in comparing these values under these heads with those derived from other products, it is desirable to draw attention to the fact that the term " agricultural output " in this connection means " the estimated quantity of produce sold by farmers to the non-farming community together with the quantity consumed in farm households." As considerable quantities of the crops raised on the farm are consumed by stock, the " live stock " division obtains an advantage at the expense

AGRICULTURE, BRITISH ISLES (*Continued*)—
of the "farm crops" division, but one, nevertheless, that could not upset the relative position of the two divisions.

Of the total gross value of £286, £225 millions or 78½ per cent. is estimated as produced in England and Wales; £48 millons or 17 per cent. in Scotland; and £13 millions or 4½ per cent. in Northern Ireland, although this understates the contribution of Northern Ireland to the extent of her store cattle output, estimated at £2,100,000 in the census year.

The percentage of value of gross output in each principal group in 1925 is shown for England and Wales, Scotland, and Northern Ireland in the following table:

	England and Wales.	*Scotland.*	*Northern Ireland.*
Live Stock and Live Stock Products :			
Live Stock	35·0	54·9	36·4
Milk and Dairy Produce ..	25·6	18·5	19·4
Poultry and Eggs	6·7	4·7	22·2
Wool	1·3	2·3	0·4
Total	68·6	80·4	78·4
Farm Crops :			
Grain	10·7	8·4	1·5
Potatoes	5·3	6·4	8·5
Hops, Flax, Sugar Beet, Seeds, Straw and Hay, etc.	4·5	3·1	9·0
Total	20·5	17·9	19·0
Fruit, Vegetables, Flowers, etc.	10·9	1·7	2·6
Grand total	100·0	100·0	100·0

The figures just given refer, of course, to gross output; and there are large quantities of materials used in the production of the various items enumerated in the table. It is estimated that the average annual value of purchased materials for the four years 1924-25 to 1927-28 is £78 millions, and if this figure is set against the value of the gross output for the same period (1924-25 to 1927-28), the value of the net output is £191 millions.

H. H.

AGRICULTURE, CANADA—Agricultural Areas—Canada, a country with an area of 3,684,723 square miles, lies for the most part in the north temperate zone. While winter temperatures are occasionally quite low, nevertheless a very large percentage of its whole area is capable of profitably producing crops of great economic importance. This possible arable area is set at about 360,000,000 acres, of which 160,000,000 acres have been taken up for agricultural purposes, but of which only about 80,000,000 acres are really under cultivated crops of any kind.

Of the approximately 10,000,000 people who live within our boundaries, about 5,000,000 are classed as farmers. This farming

AGRICULTURE, CANADA (*Continued*)—

population depends for its living on the production of wheat and coarse grains, on orcharding, on gardening, and on the livestock industry. The livestock industry so called includes horse breeding, beef production, dairy cattle exploitation, sheep raising, hog raising, and poultry keeping.

Agricultural development is much in evidence in every province. Prince Edward Island, the most easterly of the provinces, is the most intensively and completely agriculturally developed, while British Columbia, the most westerly province, is the least so. In Ontario are to be found probably the most progressive types and the greatest variety of lines of agricultural exploitation, while in Quebec, in the occupied areas at least, are to be found the most densely peopled farming districts. In New Brunswick and Nova Scotia development is limited largely to certain valleys, where it is often confined also to some special crops as, for instance, potatoes in the one case and apples in the other, with a certain amount of mixed farming in both. On the prairies in the Provinces of Manitoba, Saskatchewan, and Alberta, grain growing is practised from the eastern to the western boundary in each case, and from the southern limits to, in some cases, 700 or 800 miles north of the International Boundary.

Agriculture has been the basic industry of Canada ever since it was a Dominion, and long before. In Nova Scotia the earliest efforts at crop production date back to 1607, while in Quebec, on the present site of the city of Quebec, Louis Hebert cleared some land and grew grain in 1617. Since these earliest days agricultural development has been fast or slow, as favoured or hindered by world economic conditions, or affected by the fortunes of war. The period of most rapid growth or development was the first decade of the present century, when millions from far and near poured into and spread over the fertile virgin lands of the prairie Provinces of Saskatchewan and Alberta. Settlement of these lands was made possible by research in agriculture as carried on by individuals and by Government agencies, as will be shown elsewhere in this article.

RESEARCH WORK IN AGRICULTURE—In Canada, research in agriculture, properly so called, dates back less than fifty years. In 1887 the Dominion Experimental Farms System was organized by the Dominion Government, as the first research branch of the Department of Agriculture. At its inception this system consisted of the Central Farm at Ottawa, and four outlying farms, one in the east, one in Manitoba, one in Saskatchewan, and one in British Columbia. The administrative and research staff of the system included only nine technical men and a few clerks and experienced labourers. This original nucleus of research workers has grown and subdivided into branches and divisions until now there are about thirty Experimental Stations in different parts of the Dominion, and eight distinct branches in the Department of Agriculture, each including a number of divisions, and in the work carried on by which are employed many hundred technical men.

AGRICULTURE, CANADA (*Continued*)—

The amount of research work and propaganda carried on by this staff is very great. The effects of the research work done by these workers are difficult to estimate, and impossible in a brief space even to refer to by name, much less discuss. It will have to suffice to mention a few of the more important findings, and discuss briefly their affects upon Canadian agricultural development.

Marquis Wheat—The first problem to confront the newly appointed research men was the discovery of, or the breeding of, wheat that would permit of the growing of good quality wheat on the vast prairies, then lying practically untouched, west of the Great Lakes and east of the Rockies, a stretch of grass-clad country a thousand miles from east to west, and none knew how far from south to north. The task was difficult, but the first great step forward was the production, after much breeding work with wheats from every wheat-growing country of the world, of a variety that was named Marquis. Marquis was a hard, red wheat of excellent milling quality, that ripened from ten days to two weeks earlier than any other known or tried variety, and was at the same time more prolific and of better quality than any other wheat that could be grown with any fair measure of success on the Southern Canadian prairies, at that time supposed to be just at the northern limit of wheat production in America.

The result of the discovery of this variety of wheat was the extending of the wheat belt at least a hundred miles further north, and at least five hundred miles west. To make the above statement clear, it should be observed that as one goes west from the Red River near the eastern boundary of Manitoba, the season shortens, and so going west, to some extent at least, was the same as going north so far as wheat-growing was concerned.

Since the days when Marquis came into general use, several even earlier and more prolific varieties of wheat have been bred and are coming rapidly into general favour. The result of this work in wheat breeding is undoubtedly the bringing under cultivation of the greatest area of hard wheat-producing land in the world.

This huge wheat field now extends for nearly a thousand miles along the international boundary from east to west, and stretches no one is sure just how far north, but anywhere from, say, four hundred miles in eastern Manitoba to from seven hundred to eight hundred miles in Alberta and northern British Columbia. Some of the best crops both as to quality and yield are grown at least seven hundred miles north of the International Boundary in Alberta and British Columbia, in what is known as the Peace River Country.

The Rust Problem—In connection with wheat another line of research work of far-reaching importance is now under way and well on the road to success. This is the work directed to the control of wheat Stem Rust (*Puccinia graminis*).

This problem of finding some way of combating Rust was attacked some ten or twelve years ago, and already a number of varieties, apparently immune to any of the many kinds of wheat Stem Rust

AGRICULTURE, CANADA (*Continued*)—

that visit the Canadian prairies, have been bred and are being developed. It is estimated that one year with another Canada loses through this scourge over 25 million bushels of wheat. The importance of saving this vast amount of grain each year is, of course, very difficult to estimate. (See Diseases of Cereals, under Wheat.)

Agricultural Machinery—Still another development in connexion with wheat production is under way in Canada. Its importance is great, just how great no one may estimate at the present moment. This is the evolution in production methods. The pioneer in wheat production on the prairies started with the ox, the single-furrow plough, and the scythe. Later, came the gang plough and the binder, followed closely by the tractor with multi-gangs and squads of binders, and now are coming still more effective machines for cultural and seeding operations, and the "combine," a harvesting machine that cuts and, at the same time, threshes the grain. The double operation is done very quickly and very thoroughly by this machine. The result of all this is a tremendously increased power of production with many less men needed, and greatly reduced costs of production per acre and per bushel.

Early-maturing varieties of wheat grown with the aid of labour-saving machinery make the production of this cereal as to quantity on the Canadian prairies merely a matter of demand. The greater the demand or outlet for this and other cereals the greater will be the supply.

Moisture Supply a Problem—There is, however, as a condition of this production a very vital requirement, and that is sufficient moisture. The rainfall on the prairies is low. In Manitoba it is 18 to 20 ins. per annum, in Saskatchewan from 15 to 17 ins., and in Alberta it varies from 8 to 12 ins. in the south to from 18 to 20 ins. in the Peace River country. Ordinarily speaking, this is not enough to permit of the proper development of a good crop of wheat, and the early settlers soon found this out.

Dry Farming—One of these pioneers, Mr. Angus Mackay of Indian Head, Saskatchewan, made a happy discovery when working some land on his homestead about the year 1885. Due to lack of moisture, the seed in a certain field failed to germinate, and he decided to plough it up in June after his seeding was all done, and to treat it as a bare summer fallow through the summer to be ready for the next spring's seeding. The next year the crop on this field was incomparably superior to that on any other part of his farm or in any other field in the district. The problem was solved. By the use of the bare summer fallow the average farmer is able to ensure two good crops in three years, or, in areas where rainfall is a bit more generous, three crops in four years, one year being bare summer fallow in each case. This system is now practically universal on the prairies. As a result of its introduction grain-growing under what are called "dry farming methods" (that is, the use of the summer fallow for moisture con-

AGRICULTURE, CANADA (*Continued*)—

servation) is followed in almost every part of the west where moderately strong to strong soils maintain. (See Agriculture, Australia.)

Irrigation—Not infrequently one may see on one side of the highway in Southern Alberta great fields of grain flourishing due to irrigation, and on the other, just as abundant crops on fields handled under dry farming methods. The difference is, however, that should a succession of very dry years occur, as sometimes happens, then dry farming may prove not so satisfactory, and besides one year in two, one year in three, or, possibly at best, one year in four, the land must be idle, non-productive, and in summer fallow, whereas, of course, with irrigation every year brings a crop. There is, too, the additional very important advantage that almost any crop, cereal, potato, sugar beet, alfalfa, grass, or anything else may be grown " under the ditch," while cereals only or almost exclusively can be grown under " dry farming " methods. The irrigated areas are, of course, confined to those districts where rivers flow down to the plains from the mountains, and so can be tapped at high levels for irrigation water. The irrigation areas on the prairies extend about two hundred miles north of the International Boundary, and stretch eastward from the Rocky Mountains for about the same number of miles. It must be noted, too, of the land included in this block, probably not more than 10 per cent. is either irrigated or irrigable.

Value of Leguminous Crops—In Eastern Canada probably the most striking progress and development in crop production may be attributed to the discovery, some years ago, of the power of the legumes, clover and alfalfa, to draw upon the air for their supplies of nitrogen, in part at least. The tremendously fertilizing effect of a crop of clover or alfalfa has led to the very general introduction of short rotations in the cropping systems in practice, thus materially increasing the crop-producing powers of our farms in these eastern or older parts of the Dominion.

This fertility-restoring process has been materially helped, too, by the discovery that the possibilities of growing legumes, particularly alfalfa, might be greatly increased by the use of cultures wherewith to inoculate the soil with the bacteria peculiar to the nodules found on the roots of the particular legume it was desired to grow, and so insure the production of a profitable crop. The Province of Ontario is now so generally inoculated that practically no further effort is needed along this line, and alfalfa has become a common and a staple crop. Other crops and the livestock of the country are greatly benefited as a consequence.

The Silo—As another striking example of evolution and progress in agriculture in Canada should be mentioned the very wide use made of the silo. The discovery that green, fresh vegetation could be preserved in the silo in a succulent, palatable form, with but little loss in nutritive value, has been of great value to the Canadian farmer, more particularly, of course, to the eastern man.

The use of the silo in Ontario is practically universal. In Western

AGRICULTURE, CANADA (*Continued*)—

Quebec conditions are similar, while in Eastern Quebec, in New Brunswick, Prince Edward Island, and Nova Scotia, it is also used fairly extensively on the large livestock farms, but is by no means nearly so commonly met with as in Ontario and Western Quebec. It is also in common use in some parts of British Columbia, and, to some extent, on the prairies.

The crops that have been found most suitable for ensiling are in order of merit and popularity: corn (*Zea mays*), sunflowers, green oats and peas, and legumes (clovers, alfalfa, and sweet clover); but it should be added that almost any succulent nutritious vegetation may be satisfactorily and advantageously preserved in this way.

The silos used are usually round, from 9 to 25 ft. in diameter, and from 20 to 40 ft. high. They are built of wood (staves usually) or cement, or tile, or stone, or may consist of a pit in the side of a hill. The hollow tile silo is probably the best, with the stave silo the most common.

Livestock of all kinds will eat the ensilage, but its use is usually confined to cattle, which like it and thrive on it, especially when there is mixed with it, prior to feeding, or given as a separate part of the daily ration, a fair proportion of dry forage as straw, hay, clover or alfalfa, particularly, of course, the last.

CANADIAN CROPS—To give some idea of crop production in the Dominion it should be stated that crop production in the Dominion, as an average of the last six years, was as indicated below:

Wheat: 25,000,000 acres yielded 422,000,000 bushels, an average of 19 bushels per acre. Oats: 13,250,000 acres yielded 417,000,000 bushels, an average of 31½ bushels per acre. Barley: 3,750,000 acres yielded 102,000,000 bushels, an average of 17 bushels per acre. Rye: 750,000 acres yielded 13,000,000 bushels, an average of 17 bushels per acre. Clover and hay: 11,700,000 acres yielded 20,000,000 tons, an average of 1·70 tons per acre. Alfalfa: 742,000 acres yielded 1,813,400 tons, an average of 2·44 tons per acre. Corn for ensilage: 500,000 acres yielded 8,000,000 tons, an average of 16 tons per acre. Potatoes: 556,000 acres yielded 80,000,000 bushels, an average of 144 bushels per acre.

Besides the above, considerable quantities of turnips, mangolds, sugar-beets, rape, corn for grain (10,000,000 bushels), millet, beans, and sunflowers (for ensilage) were grown.

LIVESTOCK IN CANADA—Canada is a country capable of carrying large numbers of livestock of all kinds. As a matter of fact, however, the livestock population of the Dominion is rather small. In 1929 it was estimated that there were 3,376,487 horses, 5,152,711 beef cattle, 3,778,277 dairy cattle, 3,728,309 sheep, 4,381,725 swine, and 60,899,782 poultry in the whole Dominion. This is rather higher than was found to be actually the case, according to the census of 1921, but was not considered satisfactory.

Horses—Due to the ever-increasing use of the automobile and the tractor, horses are becoming less numerous and likely to go still lower

AGRICULTURE, CANADA (*Continued*)—

in number. They are, however, still being bred to a considerable extent, the prevailing breeds being Clydesdales, Percherons, Belgians, Thoroughbreds, and Standard Breds or road horses.

Beef Cattle—Beef cattle are bred in limited numbers in the Maritime Provinces and Quebec, but form, probably, the major part of the cattle population in Ontario, on the prairies, and in British Columbia. Ranching—that is, running beef cattle on pasture the year around, with, in some cases, feeding them with hay outside when weather is bad or grass scarce in winter—is done in Saskatchewan, Alberta, and British Columbia. Land settlement and better breeding methods are gradually reducing the areas devoted to this system of producing beef, which, while very economical as to labour, is extravagant as to land, and not particularly well suited to the breeding of high-class pure-bred stock. The beef cattle industry in Canada has not proved as attractive to the small farmer as the dairying industry, and so the relative importance of the two is gradually changing to the disadvantage of the former.

Dairy Cattle—The dairying industry, or the handling of dairy cattle, is becoming more and more important in this country, and that not only in the eastern provinces, but in every part of the Dominion. Progress is indicated by the fact that whereas in 1911 the dairy cattle numbered 2,595,255, there are now 3,778,277 cattle of this type in the Dominion. As another way of indicating progress made in this line, the produce of our dairy herds in 1911 was worth $103,381,854, while in the year 1928 it was worth $297,625,347.

The breeds most commonly handled are Holsteins, Ayrshires, Jerseys, Guernseys, Shorthorns, and French Canadians. Holsteins are by far the most popular breed, and are found in large numbers in every province. Ayrshires, too, are spread over the whole Dominion, but are most popular in Quebec. Jerseys, likewise, are found in every province, but it is in Ontario where they are bred in greatest numbers. Guernseys are kept in but limited numbers in any province, and are to be found practically not at all on the prairies. Shorthorns may be met with in all parts of the Dominion, with easily the greatest number in Ontario. The French Canadian is found almost exclusively in the Province of Quebec, but is not very commonly met with even there.

Dairy Products—Butter and cheese are the products manufactured from the milk, with butter much more commonly produced than cheese. Cheese, while made in large quantities in Quebec and Ontario, is not much to the fore in any other parts. In some districts the milk is sent to condenseries; this, too, is pretty well confined to Ontario and Quebec, with comparatively little in the latter province. The production of milk in fluid form for city use is, of course, of tremendous importance, and goes on in every province. Butter, for the most part, is made by factories commonly located in villages or towns, and usually not very large as such factories go. Some small quantities are still made in the homes of the farmers, but this practice is gradually falling off, and is usually followed only where sending the cream or

AGRICULTURE, CANADA (*Continued*)—

milk to a factory is not practicable due to transportation difficulties.

Cheese is invariably made in factories, usually quite small, and located in the country at points conveniently reached by the milk producers. Production is not so great now as in past years, and butter seems to be gaining ground on it. This is due to the great value of the skim milk to the farmer in his work of raising young stock, hogs, and poultry.

Sheep—The sheep-raising industry, while highly profitable, whether in a domestic way or on the range, has not made much, if any, progress in fifty years. The breeds commonly met with are the British medium-wools: Shropshires, Oxfords, Hampshires, and Suffolks; the long-wools: Leicesters, Cotswolds, and Lincolns; and the short-wooled breed, the Southdown. On the sheep ranches, confined to Alberta, Saskatchewan, and British Columbia, the Rambouillet is the popular breed. (See Wool.)

Swine—Hogs are bred in all parts of the country, and do well in every province. The number kept has been gradually increasing, but seems to be subject to great fluctuation.

The hog population in 1929 was 4,381,725, while in 1911 it was 3,634,778. Hogs of the type suitable for the making of Wiltshire sides are most commonly in evidence. The breeds favoured are the British: Large Yorkshires, Berkshires, and Tamworths, with a few of the fat or American hog type in certain districts.

The Large White or Yorkshire is easily the dominant breed. The bacon produced in Canada from these hogs is recognized as being quite the equal of that produced anywhere else in the world.

Goats—Goats are kept in very small numbers. They are found to some extent in Nova Scotia, Ontario, and British Columbia.

Poultry—One of the most prosperous lines of livestock exploitation, if it may be so called, is the poultry-keeping industry. The class most commonly handled is the barnyard fowl, but turkeys, ducks, geese, and pigeons are all bred in considerable numbers in all parts of the Dominion.

The present poultry population is in the neighbourhood of 60,000,000; this is a very decided increase over ten years ago, when it was 34,645,238. The breeds most favoured are Barred Rocks and White Leghorns, but many others are in evidence.

Great progress has been made in this industry in recent years, both in the quality of the birds kept and in the character and quantity of the produce, whether it be eggs or dressed fowl. Prince Edward Island, Ontario, and British Columbia are the provinces in which most attention is given to this industry. The production of hen eggs is estimated at about 350,000,000 dozen per annum.

FRUIT—As a fruit-producing country, Canada does not take a very prominent place in the world, save in the case of apples, pears, peaches, prunes, plums, apricots; cherries and grapes are, however, grown in considerable quantities in certain districts. Bush fruits—that is, red, white,

AGRICULTURE, CANADA (*Continued*)—

and black currants, and gooseberries—are grown in every province. Small fruits such as strawberries, raspberries, and blackberries are also grown in many parts of the Dominion, while blueberries grow wild and are harvested in large quantities in all the eastern provinces, save Prince Edward Island.

On the whole, it may be said that fruit production is an important industry in Canada, and is increasing fairly rapidly. The area devoted to this industry in the Dominion is estimated to be about 300,000 acres.

Apples—Canadian apples are recognized wherever they are sold as being of superior quality and of very fine appearance. There are four main areas in which they do exceedingly well. These are the Annapolis Valley in Nova Scotia, the south-western part of Quebec, that part of Ontario lying south of a line from Ottawa to the southern end of Georgian Bay, and the Okanagan Valley in British Columbia, although in this province apples do well in various other districts. Many varieties are grown, but probably the best known and most popular are McIntosh Red, Northern Spy, Gravenstein, Ribston, Delicious, and King. The estimated production in 1929 was 10,000,000 boxes.

Other Tree Fruits—Pears are grown in Nova Scotia, Ontario, and British Columbia, but to a rather limited extent only. Peach orcharding is confined pretty well to the Niagara Peninsula in Ontario, and the Okanagan Valley in British Columbia. Production is increasing in British Columbia, but falling off in Ontario. Plums of one kind or another are produced in every province. Prunes are grown to only a limited extent in British Columbia, but production is increasing. Apricots also are grown in small quantities in British Columbia, while cherries are grown to some extent in Nova Scotia, and fairly extensively in Ontario and British Columbia.

Fruit Canning—The stone fruits just discussed are canned in large quantities, as are also the bush fruits and small fruits mentioned above. The principal canning plants for this purpose are located in Ontario, British Columbia and Quebec.

Vegetable Canning—The canning of vegetables is carried on quite extensively in Ontario, British Columbia and Quebec. The tomato is the vegetable most extensively handled in this way, and is grown and canned in large quantities in Ontario and British Columbia. Peas, sweet corn, asparagus, and spinach are also put up in large quantities.

This industry of canning both fruit and vegetables is becoming of major importance, and the production of fruits and vegetables to supply the demands of the canneries is demanding larger and larger areas and employing more and more people every year.

SPECIAL CROPS—In addition to the cereals, forage crops, and fruits discussed above, there are grown in certain areas a number of special crops which, while not of major importance individually, nevertheless, make up a very important total. Some of the more noticeable of these are sugar-beets, certified seed potatoes, tobacco, flax for fibre, hops, onions, and maple sugar.

AGRICULTURE, CANADA (*Continued*)—

Sugar-Beets—Sugar-beet production has been carried on in every province, but has succeeded commercially for sugar making in only two areas, South-Western Ontario and Southern Alberta. There is a large factory in each of these districts, and the roots are brought to them for hundreds of miles around. The test in each area is quite high, being in the neighbourhood of 19 per cent. sugar in the juice.

Certified Seed Potatoes—Potatoes are grown in Canada to the amount of about 50,000,000 bushels each year, of which about 3,000,000 bushels are certified seed. This crop is produced in every province, with special attention paid to it in Prince Edward Island and New Brunswick. In these two provinces it is possible to grow fairly easily potatoes particularly free from diseases of all kinds, and certified or disease-free seed from these provinces finds a ready market in certain Southern States of the neighbouring Republic and in Cuba.

Tobacco—Tobacco to the extent of about 40,000,000 lbs. is grown in the Dominion each year, almost exclusively in Ontario and Quebec. Ontario tobacco is suited for plug or pipe tobacco, and for cigarettes. Quebec tobacco is used for cigars and pipe tobacco, and production is increasing in both provinces. Export is small, but quality probabilities seem to point to a considerable export trade in the near future. The flue-cured or cigarette tobacco is increasing in production very rapidly, and some crops of excellent quality are being grown.

Fibre Flax—Fibre flax of good quality can be grown in the eastern provinces and in British Columbia. It is grown on a commercial scale in Ontario and Quebec, but the high cost of labour limits its production.

Hops—Hops, at one time grown in considerable quantities in Ontario and Quebec, are now produced on a commercial scale in British Columbia alone. They are reputed to be of good quality.

Maple Sugar—As another industry of some importance in Quebec and Ontario might be mentioned maple-sugar production. This, while not exactly a farm industry, is carried on almost entirely by farmers in maple groves or orchards on their own farms. The annual production is around 40,000,000 lbs., in the form of either sugar or syrup. Production is probably increasing.

MARKETING—The marketing of the produce from the farm, the ranch, and the orchard or garden is, and has been for some time, a matter of intense interest to the producer in this country. Co-operative selling has made considerable headway, particularly in respect to wheat and coarse grains. It has not as yet, however, enlisted the unhesitating support of the majority of our farmers. Besides grains, dairy produce, livestock, fruits, and vegetables are handled to a greater or lesser extent in this way, with apples easily taking the lead.

PRODUCE GRADING—Government grading of produce is largely in operation. This service is not only available but enforced in respect of eggs, bacon, hogs, cereals of all kinds, seeds of most kinds, fruit

AGRICULTURE, CANADA (*Continued*)—
of all kinds, vegetables, potatoes, cheese and butter. In the case of wool, dressed-fowl, and beef, grading is optional, but largely practised. The effects of grading have been very marked in improving the quality of the different products mentioned.

J. H. G.

AGRICULTURE, CHANNEL ISLANDS—The agriculture of the Channel Islands is characterized by two remarkable breeds of cattle—the Jersey and Guernsey—and by the production of tomatoes, a variety of glass-house crops, and early potatoes. The climate is mild and equable, without winter as understood in England. The main islands are Jersey and Guernsey, and these differ rather widely in the style of their farming.

The former is essentially an island of small holdings, by far the larger part of the holdings not exceeding 20 acres, while perhaps fewer than half a dozen exceed 50 acres. The total area, including water, is only 28,717 acres, and of this 19,412 acres are under cultivation (15,941 acres arable, and 3,471 acres permanent grass), and a further 1,150 acres rough grazings. The farming is therefore mainly arable. In the past corn and cattle formed the basis of the farming, but at present more than one-half of the arable area is devoted to potatoes, only about one-eighth to corn crops, and nearly one-fourth to rotation grasses, etc. Open-air tomatoes commonly follow the early potatoes, which are planted very early in the new year—from January onwards, so that the crop may be on the London market in April-May. The area of glass-houses is very small. Cattle number round about 10,000, horses rather over 2,000, pigs about 3,000, and sheep are almost non-existent. The main exports are cattle (1,567 head in 1928), potatoes (61,796 tons in 1928), and tomatoes (23,702 tons in 1928).

In 1928 the imports into Jersey included cattle foods, bran, pulse, and cereals to the extent of 6,582 tons, other grains and seeds 473 tons, potatoes 1,053 tons, hay 2,274 tons, straw 2,699 tons, horses 122, and artificial manures 10,574 tons, the last figure being especially noteworthy.

The features of Jersey farming are the heavy stocking of the cattle (518 per 1,000 acres under cultivation, or 1 to 0·8 acre of permanent grass, rotation grasses and clovers, and rough grazings), the extensive cultivation of potatoes and tomatoes, the large area of rotation "grasses" (including clovers, sainfoin, and lucerne), and the considerable imports of fertilizers (about 10 cwts. per acre of the total area under cultivation). Cattle are almost invariably tethered; butter recording is general, as is the tuberculin test; liquid manure has long been conserved and applied to grass land; enormous quantities of seaweed are collected for use as manure; the average yield of potatoes is high (perhaps 4½ tons per acre in the case of earlies, 6¼ tons for second earlies, and 9 tons for main crops); and tomatoes yield about 12 tons per acre.

The total area of the island of Guernsey is approximately 15,750

AGRICULTURE, CHANNEL ISLANDS (*Continued*)—

acres, and according to the 1926 crop census 12,551 acres were owned and rented in the ten parishes. The cultivated area was 10,248 acres, the arable area being 4,420 acres and the permanent grass 5,828 acres; the glass-house industry occupied 795 acres. Whereas in Jersey the farming is mainly arable, the arable area and glass-house industry in Guernsey are together approximately equal to the permanent grass. The main crops are bulbs, potatoes, roots, grain, green crops, fruit and kitchen garden crops, and glass-house crops in wide variety. At the time mentioned the various crops occupied, to the nearest five acres, the following areas:

	Acres.		Acres.
Grain	595	Bulbs	1,100
Potatoes ..	710	Fruit and kitchen gardens ..	535
Roots	690	Other crops	265
Green crops ..	520	Glass	795
Permanent grass	5,825		

From this it will be seen that the area of potatoes is in excess of the grain acreage, while the area devoted to bulbs is almost double that of grain. The green crops are largely lucerne, clover, sainfoin, and rotation grasses. As regards the glass-house industry, enormous crops of tomatoes are produced for export, mainly to England, together with cucumbers, grapes, figs, and many kinds of flowers and decorative plants. It should be emphasised also that considerable quantities of early potatoes are produced under glass during the winter months for export between January and March, these realising very high prices.

As regards livestock, the figures in 1926 were about 5,700 cattle, 1,850 pigs, 1,450 horses, 350 goats and 31,000 poultry. It will be observed that the number of cattle per 1,000 acres under cultivation in the States of Guernsey is approximately the same as in Jersey, the figure being 550, although the percentage of permanent grass is much higher.

As in the case of Jersey, Guernsey is an island of small holders, the average holding being not more than about 5 acres. In 1928 the exports (other than to Alderney) included: tomatoes 25,069 tons, flowers 3,205 tons, grapes 1,281 tons, vegetables 602 tons, potatoes 538 tons, bulbs 409 tons, melons and other fruit 152 tons, and plants and shrubs 30 tons, together with 761 head of cattle. The imports included over 7,000 tons of cereal and other feeding stuffs, about 4,000 tons of fertilisers, and 2,350 tons of potatoes, together with nearly 1,000 tons of straw, hay, and chaff, and 1,358 tons of greenhouse glass.

From the agricultural standpoint Guernsey depends upon its cattle, glass-house industry, and bulbs. It is deserving of notice also that one particular nursery is specially devoted to tropical and sub-tropical plants. The area of glass appears to be extending yearly, but its products are increasingly subject to competition on the English market with exports from the Continent—particularly in so far as tomatoes are concerned.

H. C. L.

AGRICULTURE, INDIA—To present in simple form a summary account of Indian agriculture is a matter of some difficulty. This is due to the great variety of the climatic conditions met with in so large a tract of country and, as a consequence, to the great diversity of crops grown. In the north a hot, rainy season, following a period of intense dry heat, and followed by a cold season, permits a dual cropping system in which temperate crops alternate with crops which are essentially tropical. In the south truly tropical conditions prevail. Throughout, humidity is the determining factor, and rainfall is very variable. Except for a relatively small area subject to the north-east monsoon, the south-west monsoon exerts an all-powerful influence. Its strength varies from locality to locality. In Assam, Bengal, Burma, and the Western Ghats, the rainfall is high, Cherrapunji, in Assam, recording some 460 ins. per annum; while, in the north-west, the only rainfall occurs not in the monsoon, but in the cold weather, and averages some 5 ins. In this tract lie the desert areas of the South Punjab and Scind. It varies equally from year to year, and the maximum in any one locality may be as much as five times the minimum. The monsoon is a current of variable intensity. Periods of rainfall alternate with breaks, and the distribution of the fall is hardly less important than the total quantity. Some indication of the extent and variety of the crops grown is given by the following figures:

AREA SOWN TO DIFFERENT CROPS (IN MILLIONS OF ACRES).

Rice ..	78·5	Oil seeds	15
Wheat ..	24	Cotton	13·5
Barley ..	6	Jute ..	3·5
Other grains	88	Tea ..	0·75
Sugar ..	3	Tobacco	1
Other foods	7·5	Other non-foods	2·5
Total sown	226	Total irrigated	48

A further complexity is introduced by the economic systems which prevail. At one extreme is the "rayatwari" system, a system of small peasant proprietorships in which the peasant (rayat) holds his land direct from Government, subject only to the payment of an assessment on his holding. At the other extreme is the "plantation" system as represented by the tea estates of Assam and Bengal, the coffee and rubber estates of Southern India, and the fruit orchards of the Himalayas. Intermediate between these lies the "zemindari" system, common throughout Northern India, a system under which the peasant no longer possesses his holding, but rents it from a landlord (zemindar), who pays the assessment demand of Government.

Complex though these systems of agriculture may thus be, there are certain features which are common throughout the country. India is a country of peasant cultivation, and the unit of production is the family. The plantations occupy an insignificant proportion of the whole area, as does the personally cultivated zemindari, for the zemindar rarely plays an active part in production, and his activity is usually limited to the collection of rents from tenants, not otherwise distinguishable from the rayat of the rayatwari system. In both these systems, which are indigenous, as opposed to the plantation

AGRICULTURE, INDIA (*Continued*)—

system, which is alien, the methods of production are the same. Though increased mobility is gradually producing a change, cultivation is still primarily directed to supplying the needs of the cultivator, his family, and his cattle, and only the excess produce finds its way on to the markets to supply the cities and for export.

It will be seen from the accompanying table that the excess of exports over imports is predominantly due to non-food products, oil seeds, cotton, jute, wool, and hides, while the only large export of foods, if tea be excepted from such—namely, grains—is composed mainly of rice, of which 2,749 lakhs comes from Burma, and is largely counterbalanced by the import of that other essential food, sugar. Broadly speaking, therefore, India merely supplies its own requirements of agricultural produce, and of the total production only a fraction finds its way on to the markets. It is a country of rapidly maturing crops yielding a quick return.

IMPORTS AND EXPORTS (IN LAKHS OF RUPEES).

	Imports.	*Exports.*		*Imports.*	*Exports.*
Fruit	212	105	Oil cakes	13	314
Grains:			Oil	48	29
Rice ..	—	3,399	Paper materials	40	1
Wheat (including flour)	—	195	Rubber	—	257
Pulse		187	Cotton	674	4,819
Barley	—	85	Seeds ..	18	2,669
Maize	—	4	Jute ..	—	3,066
Jowar	—	35	Wool ..	44	456
Total grains	231	4,292	Gums, lac	60	719
Spices ..	258	240	Fodder	1	137
Tea	69	3,248	Tobacco	291	106
Other foods and drink ..	200	235	Hides ..	27	881

Note.—A rupee=1s. 6d. (approx.).
A lakh=100,000 rupees=approx. £7,500.

A further characteristic feature is the result of custom relative to inheritance. Partition is the rule, and partition which divides not only the holding, but each fraction of the holding. The result of such partition and fragmentation is that each holding is not only small, but fragmented into a number of scattered fields which, both in size and formation, are uneconomic. In zemindari tracts, which are characteristic of the more fertile north, pressure of population, combined with the absence of any alternative means of employment, has created a competition for land which has forced up rents with similar results. The peasantry lives on the margin of subsistence. Some indication of the effect of these forces is given by the following figures. In the Punjab the average holding is some 12 acres, and this is the largest figure found throughout India; in Bengal and Bihar it falls to 3 acres. In a certain village the land was divided into 1,598 fields averaging about $\frac{1}{5}$ acre each, and 28 per cent. of the holdings had over thirty fields (Darling "The Punjab Peasant"). As a consequence the peasant, as the primary producer, is concerned only

AGRICULTURE, INDIA (*Continued*)—

with production. As a class he is heavily in debt. In one particular census 17 per cent. only were free from debt, and the average debt was Rs. 463 (Darling, *loc. cit.*). Not only, therefore, has he no reserves to purchase improved implements, manures, sound seed, and so on, but his crop is frequently mortgaged in advance for a cash advance or seed. His holding is ill-adapted to take advantage of better implements of tillage; he has not the means to secure these, and, further, he has not the freedom, even if he possessed the knowledge, to secure the real value of his excess produce, most of which is handled by the village "bania," who also acts as money-lender.

Superimposed on this fundamental similarity, due to the human factor, lie those modifications of practice which are the consequence of climatic and other natural factors. The centre of this complex system may be taken to lie in the Gangetic plain, and to include those easterly portions of the United Provinces and that fraction of Bihar and Orissa which lie in that plain. Here an adequate, and relatively certain, rainfall (June to early October), a mild cold weather (October to February) and a hot weather (March to June) lacking the severity experienced further west, reinforced by a deep alluvial soil having a water table kept sufficiently high by seepage from the Himalayas, combine to provide conditions which permit plant growth to continue throughout the year without irrigation. Light irrigation from wells may be resorted to, but some indication of the supplies of moisture available for crop growth may be gathered from the practice with indigo before the introduction of the Natal-Java plant (*I. arrecta* Hochst.), when the plant grown was *I. Sumatrana* Gaert. The seed was sown after careful preparation of the land in early March, though frequently no rain had fallen since the previous September, and no rain might fall till June after the hot weather. Here is one centre of cane cultivation, with modern factories to handle the cane. Here the standard cultivation of the peasants' holdings consists of the "rabi" (cold season) crops, sown at the end of October, of which the more important are wheat, barley, peas, tobacco, linseed, rape, and mustard. These are reaped in March at the commencement of the hot weather, and followed in June, with the commencement of the rains, by the "kharif" crops, chiefly maize, jowar (*Sorghum vulgare* Pers.), bajra (*Pennisetum typhoideum* Rich.), and pulses, mung, and urd (*Phaseolus* spp.). Arhar (*Cajanus indicus* Spreng.) is extensively grown, the crop being sown in June and harvested in March, while, to a lesser extent, til (*Sesamum indicum* D.C.) is cultivated as a "rains" crop. In the low-lying tracts rice is extensively cultivated. The soil, except in the low-lying areas which form jheels (swamps) in the wet season, where it is heavy, is a light alluvium through which a capillary rise takes place from the water table at 15 to 20 ft. It is a flow which cultivation can do much to regulate, and the skill of the cultivator in this regulation is of a very high order. Tilths produced by repeated ploughings with a plough which merely scratches the surface 5 ins., followed by the "patha" (wooden beam), are nowhere in the world carried to the same degree of fineness.

AGRICULTURE, INDIA (*Continued*)—

To the east of this tract the deltaic area of the Ganges and Brahmaputra is approached. With its higher rainfall, rice assumes greater and greater importance until it becomes the dominating crop. With its numerous varieties adapted to a wide range of conditions, rice is found in Bengal at all seasons. There are two main crops: "aman," or winter rice, sown in May on low lands and reaped in December and January, and "aus," or summer rice, sown in April-May and reaped in August and September. Further east, passing into Eastern Bengal and Assam, occur the flooded areas in which jute competes with rice in importance, while in the hilly tracts of Bengal to the north and Assam to the north-east lie the tea "gardens."

To the west a different change is found, largely as a consequence of an intensification of the climatic factors. A diminishing and more uncertain rainfall is accompanied by an increasing intensity of cold in the cold weather and of heat in the hot weather. In the centre and west of the United Provinces, moisture becomes definitely deficient, and the extent of the unirrigated rabi area is very variable and intimately associated with the extent and lateness of the preceding rains. Here stability is secured as far as possible by the development of an extensive and intricate canal system. The Upper and Lower Ganges canals, the Eastern Jumna canal, and the recently opened Sarda canal draw their supplies from the Himalayan rivers whose names they bear. Large though the area commanded is, it is but a fraction of the total area cultivated, and their function is definitely protective. They divide their supplies over the area commanded, and those supplies are regulated less in accord with the requirements of the crops than with the available supply. The rabi crops are essentially the same, but wheat becomes the dominant crop, while of kharif crops, owing to the lower rainfall, cotton assumes a growing importance until, in the south-west, it occupies nearly a third of the kharif area. The soils, except along the narrow submontane tract, where they retain the characteristics of those of the first tract described, are an older alluvium. The flow of water from the water table is no longer apparent, and crops are dependent on natural precipitation with such additional supplies as man can provide. With the completion of the Sarda canal the limit of canalization is reached, and further supplies must come from the ground water. Wells are common, and a recent development of considerable importance is the tube-well, one of which is capable of protecting as much as 400 acres. Arid conditions begin to assert themselves and, especially in the west, large stretches of infertile usar (barren) lands are found. They are typical alkaline lands often showing the characteristic efflorescence.

With a gradually increasing intensity of these climatic conditions the arid tract of the Punjab and the Indus valley is reached, a tract with little or no monsoon rainfall and a cold weather fall of some 5 ins. The agricultural importance of these "canal colonies" is due entirely to the vast system of canals which draw their water from the five rivers of the Punjab. This tract, which includes the Scind area of the Bombay Presidency, will receive a large increase with the

AGRICULTURE, INDIA (*Continued*)—

completion of the Sukkur barrage across the Indus. Here the main crops are wheat (rabi) and cotton (kharif). The main agricultural problem is concerned with the rise of the water table as the result of liberal irrigation and the consequent development of alkali.

The whole of the area so far considered is alluvial, the detritus deposited in their beds by the Indus and its tributaries, the Jumna, the Ganges, and the Brahmaputra, with a number of lesser rivers which have their rise in the Himalayas. When the Jumna valley is crossed, a very different system of agriculture is found. There are no lofty ranges to feed perennial rivers, and irrigation is limited to the impounding of water during the rains for subsequent use in the dry weather. There is not the inexhaustible supply of ground water readily available, and wells are both difficult to construct and limited in supply. Before the uplands of Central India is reached, there lies that agriculturally unimportant, but very interesting, tract of Bundelkhand. Protected by a few minor canals, the tract is generally dependent on rainfall, and the rabi crop more particularly is precarious. Its interest lies in the fact that here is found an agricultural practice which seems to be in the nature of insurance. The rural population is poverty stricken, and is unable to risk the failure of even one crop. To suit these conditions there has been evolved a system of mixed cropping in which wheat (mainly a Durum type), barley, linseed, gram, peas, and mustard are all sown intermingled. Though a bumper crop is never obtained, the cultivator is practically assured of some return whatever the season.

Further south the Uplands of Central India are reached. They are characterized by a lessened intensity of the cold of the cold weather and of heat in the rainy season. The soils are nowhere deep, and overlie rock. They are mainly basaltic, and there are large stretches of "regur," the so-named black cotton soil. Cotton becomes the main crop over large areas, while millets replace wheat as the staple food crop. Rice is common where the requisite water supply is available, and on irrigated areas sugar cane is grown.

Cultivation to the south, in the Deccan, differs in no material respect from that above, though the soils gradually assume a predominance of laterite. The whole tract is one of moderate rainfall, the intensity of the south-west monsoon current being broken by the higher altitudes of the Western Ghats.

In the extreme south, in Madras, cultivation is governed in the east by the north-east monsoon, and in the west by the south-west monsoon. Cultivation is extraordinarily varied, and sometimes differs markedly within a few miles. In the drier areas, cotton and millets form the bulk of the crop; in the wetter areas cane, rice, and spices are grown, while the sea coast is marked by the coconut. On the West occur the plantations of coffee and rubber, while in the Nilgherries cinchona is grown on a plantation basis.

The question of the improvement of Indian agriculture is a complex one incapable of any spectacular solution, for it is intimately bound up with the question of improving the economic condition of the

AGRICULTURE, INDIA (*Continued*)—

Indian rayat. Primarily it is a question of increasing the productive capacity of the land, for undoubtedly the rayat is a potential consumer of a larger portion of his own produce than he is at present. There is, too, a large floating population subsisting on the coarser grains and pulses which would, under better conditions, turn to wheat. The major portion of the cultivated area of the country has been under the plough for centuries. The inundated areas of Bengal and Assam no doubt receive annually a deposit of silt which adds to the fertility of future years; the Punjab canal colonies may still retain some of their virgin fertility; bordering each village there is a certain area of "'gohan" land which, receiving the village refuse, is of high fertility; but for the rest, and this is by far the larger area, it will not be far wrong to say that the basic minimum of production has long been reached. Wheat averages 13 bushels, maize 15½ bushels, cotton 98 lbs., cane 6 tons; values which are found elsewhere under an extensive system of farming, while the Indian system is in its main essentials intensive. The primary question, therefore, is one of raising the fertility of the soil.

A consideration of this aspect raises at once the economic side of the problem. Under the hot conditions prevailing, bacterial activity proceeds at a rate unknown in temperate climates, and the visible sign of that activity is loss of humus. Deficiency of organic matter is the outstanding feature of the soils of India. Of this the "gohan" lands are a sufficient indication. With adequate organic manure, yields up to 50 bushels of wheat and 40 tons of cane have been secured under conditions which normally give 20 bushels and 12 tons respectively. But it is a deficiency which it is difficult to make good, for in spite of their large population, cattle return little to the land. They are not bedded down; straw is consumed as fodder, and the droppings made into cakes which are dried and burned. These form the main fuel in a country where natural reserves are wholly inadequate. The solution of this agricultural problem is economic in that it is to be solved by the provision of an alternative supply of fuel within the purchasing capacity of the general rural community. The agricultural solution of stall feeding or, as in Egypt, the tethering out of cattle, raises the equally difficult problem of the addition of specific fodder crops on holdings already too small. Green manuring raises problems similar to tethering, and is, moreover, subject to risks in a country with a precarious rainfall. Artificials, too, are practically unknown, and it is questionable whether a return commensurate with their cost would be obtained so long as the humus problem remains unsolved.

The two important tillage implements are the plough and the beam, or "patha," the latter of which is used to work up a tilth. The country plough, in any of its multitudinous forms, merely breaks up, without inverting, the surface 4 to 5 ins. The advantages of deeper ploughing with inversion have been amply demonstrated; similarly, the advantage of ploughing the land after the rabi, so that it is exposed to the heat and winds which precede the rains, has been

AGRICULTURE, INDIA (*Continued*)—

demonstrated. Ploughs within the draught capacity of the cattle are available, yet the market for these remains insignificant while fields remain as before unploughed till softened by the first rains. Here again the explanation must be sought in economic causes. That the cultivator is alive to the advantage of early ploughing is apparent, for an exceptional rain in April, which softens the ground and delays harvest, brings every available plough out. That he does not adopt it as a normal practice is due to the fact that his cattle are occupied to the extent of their power in threshing the grain. He does not buy an inverting plough because it is an addition to his equipment which he can ill afford, unsuited for the preparation of the seed bed. Moreover, its first incautious use may be to destroy tilth by too great a dilution of subsoil. Certain though the ultimate benefit may be, there is an initial risk which he can ill afford to take.

The Indian cultivators, especially those of the agricultural castes, are highly skilled in the practice of tillage, with a skill embodying the accumulated experience of generations. But that experience has failed to supply in like measure a knowledge of the plant itself. Anything more than a superficial recognition of varietal differences, except in the case of cane, and this, perhaps, for the reason that it is vegetatively reproduced, is not recognised. It may be that this, too, is to be traced to economic causes, for a pure crop is exposed to risks that a mixture is not, and varietal mixtures offer an insurance suited to his economic circumstance. It is also true that the supply of markets is a secondary consideration, and the need for supplying a graded product is not, therefore, a vital matter. Such varietal forms as are found appear to be the result of a natural process of selection in which the form best adapted to the local conditions assumes a dominance which is rarely complete. It is a condition which has offered an opening for immediate improvement, and much work has been done in the selection and breeding of improved races. Most of the standard crops have been analysed, and selected races of many are now grown over a considerable area. Particularly is this the case with wheat, cane, jute, rice, millets, and cotton, though the latter offers a more complex problem in that, though the value of cotton lies in the quality of its staple, its value to the cultivator, who sells it as seed-cotton (kapas), lies largely in its ginning percentage.

But here again the advantages of such improved varieties is largely annulled by the economic condition of the cultivator; full advantage of their potentialities is not reaped. In recent years there have been introduced a number of strains of wheat with the capacity of giving greatly enhanced yields, and though the area under these is considerable, it remains small compared with the entire wheat area. Thus, the area under improved wheat in the Punjab is estimated at only 12 per cent. of the total wheat area of that Province. The failure of these improved strains to spread is not due to any unsuitability in the strain itself, for some are fully capable of yielding 50 bushels and over. They have a strength of straw to carry a crop which the weak-strawed indigenous varieties would never carry and remain

AGRICULTURE, INDIA (*Continued*)—

erect; but this intrinsic superiority remains potential. The cultivator will not reap the benefit which these improved strains are capable of yielding until he can, by better tillage, by the application of manure, and especially by the addition of humus, improve the heart of his land. The 2 to 3 bushels increased yield with which these strains are credited are but a fraction of the potential increase, and, moreover, too small for that easy recognition which would create a real demand. Too often the demand for supplies from the seed depôts organized by Government, from which the seed of these strains is issued, arises less from the knowledge of the potentiality of the strain than from the knowledge that the seed so issued has been well stored and is of trustworthy viability.

These few examples are sufficient to show that it is the economic condition of the cultivator which lies at the root of the problem of Indian agriculture. Only when a material improvement in that condition has taken place will the work of the last thirty years bear its full return. The fundamental problem is economic; it is a problem which has not been neglected. Fragmentation has been met in a few instances in the Punjab by "restriping," and partition, particularly in the canal colonies, has been restricted by law. The whole history of agrarian legislation in the United Provinces, in which the zemindari system prevails, constitutes an attempt to protect the cultivator and strengthen his economic condition. But the greatest effort has been made in co-operation. Since the first Act of 1904, co-operation has proceeded apace, and there is now a highly developed co-operative organization with some 90,000 primary societies, a superstructure of central banks, and a working capital of 70 crores. Extensive though this organization be, it is small compared with the needs. Its 3½ million members form but a fraction of the total population of 320 million, of which over 70 per cent. are directly concerned with agriculture. It is, further, almost entirely confined to meeting the credit position, for there are only some 2,400 non-credit societies. The development of the system for the supply of seed, manure, and so on, and to market the produce, remains for the future, and it is only when this system is developed in all its branches that such a real improvement of the cultivator's economic position will result that he will be in a position to take advantage to the full of the benefits of improved practice.

In rayatwari tracts, co-operation offers the only solution of the agricultural problem, for there is no outstanding centre around which organization can crystallize. In zemindari tracts this is not the case, for the zemindar himself forms such a centre. In the past he has rarely figured as more than a rent collector, and not infrequently he has been an absentee. But during the war and the immediately succeeding years prices soared more rapidly than rents could be raised, and the desire of zemindars to secure to themselves a larger portion of that rise than was recoverable in rents turned the attention of not a few to the establishment of home farms. The movement survives in spite of the reaction in prices, and is one which offers a promising field and method for the introduction of improvements.

AGRICULTURE, INDIA (*Continued*)—

Indian agriculture is predominantly a system of crop production, but a general survey cannot ignore the question of stock. Except in Gujerat, where the conditions approach reaching, and from which a considerable export of ghee takes place, especially to East Africa, the most important function of cattle is to plough the fields. The cow is the producer of the bullock, and its function as the supplier of milk is a secondary one which it shares with the buffalo. In the neighbourhood of cities, and within the city itself, the cow has a definite function as a milk supplier, but elsewhere this is not the case, and even here any organization of a milk supply is practically unknown. Milk yields are, consequently, low; a Montgomery cow will yield some 2,500 lbs., and the Montgomery is a milking breed, while the Delhi buffalo yields some 4,000 lbs.; but a breed like the Kherigarh shows a yield of only some 500 lbs. per cow. Meat, except in tracts with a population preponderatingly Mohammedan, is not consumed. The cattle problem orientates round the bullock as a working unit, and in this respect differs materially from the cattle problem of other countries.

The whole question of cattle is further bound up with religion, and this bond cannot be ignored in any consideration of the efficiency of cattle as workers. The religious prejudice against killing enforces the carrying a load of inefficient animals, too old to work, and consuming the barely sufficient fodder supplies. It is religion, too, which dictates the practice of leaving service to the bull, frequently of unknown stock, dedicated and turned adrift to roam through the countryside. It is this religious background which renders the problem of raising the efficiency of the cattle so difficult. The pressure on the fodder supplies is great and, in event of a failure of the rains, a large mortality takes place. But the damage does not end there. Young stock suffer to an extent which renders them permanently weak and inefficient. Yet a solution of the problem must be found if the main problem of agricultural improvement is to be solved. For better tillage demands stronger cattle, and stronger cattle will only result when fodder supplies are not shared with the inefficient, and when the importance of the bull receives due recognition. The solution, though a partial one only, seems to lie in the organization of charitable endowments to remove the aged and unfit to tracts where population is sparse and natural grazing available. It is a solution in accord with religious sentiment, and to which the liberal endowments might well be diverted. But a full solution must await the increase in the value of stock which alone will justify the raising of fodder crops as such and create a market for well-bred stock. It is a problem of fodder crops versus food and cash crops. The solution must be a slow process, for the uneconomic holding places a premium on food crops, and that premium, in its turn, results in poor stock, and inability to support vigorous stock means absence of a market for well-bred cattle. It is a vicious circle to be traced yet again to economic causes.

H. M. L.

AGRICULTURE, IRISH FREE STATE (SAORSTAT EIREANN)—The high productivity of the land of the Irish Free State is due not only to the inherent fertility of the soil, but also to the humidity of the climate and the mild, equable temperature. The population of the country, as shown by the 1926 census, was 2,971,992. Of all occupied persons rather more than half are employed directly in agriculture. Out of a total of approximately 17,000,000 statute acres, 12,250,000 acres are returned as under crops and pasture. There are approximately 350,000 holdings over 1 statute acre in extent, and of these 65 per cent. are under 30 acres. Under successive Land Purchase Acts, the first of which was enacted in 1885 and the most recent in 1923, 1925, and 1927, the ownership of most of the land has been transferred to the occupiers subject to the payment by them of terminable annuities. Under the provisions of the Land Acts arrangements have also been made for the enlargement of uneconomic holdings in certain districts and for the transfer of occupiers thereof to economic holdings specially provided for the purpose on estates purchased by the Irish Land Commission.

The system of agriculture most widely practised is that generally known as "mixed farming, *i.e.*, the breeding and rearing of live-stock combined with a proportion of arable farming. Commercial dairying for the production of cream and of creamery butter is mainly carried on in the south and south-west, to a less extent in the northern counties, and hardly at all in the midlands and west.

The markets of Great Britain are the chief outlet for the surplus agricultural production, and the various legislative measures to which reference is made in subsequent paragraphs have as their chief object such improvement of stock and produce as will enable the exports of the Irish Free State still better to meet the requirements of those markets.

Improvement of Arable Crops—As a result of several systematic series of manurial experiments which have been conducted throughout the country by the County Agricultural Instructors, what are termed standard mixtures of fertilizers for the various crops are now in general use, many of them being compounded and sold by the Irish manure manufacturers as "the Department's Formula." Variety trials, similarly conducted, have resulted in the introduction and general use of improved varieties of cereals, potatoes, and roots.

In 1905 a Plant Breeding Station was established at Ballinacurra, Co. Cork, where, in 1908, Dr. H. Hunter made the cross which resulted in the production of Spratt-Archer barley, now so generally grown in this and other countries. Experimental work with barley at Ballinacurra has been continued with the object of producing more prolific strains. In co-operation with Messrs. A. Guinness, Son and Co., Ltd., and the Irish Maltsters' Association, large foundation stocks of pedigree seed barley are distributed annually for propagation for seed purposes and the purity of the malting stocks is thus maintained.

At the Plant Breeding Station which was subsequently established at the Albert Agricultural College, Dublin, which is now controlled by the Agricultural Faculty of University College, Dublin, several

AGRICULTURE, IRISH FREE STATE (*Continued*)—
promising varieties of oats have been produced, and foundation stocks of these, as well as of pure line stocks of older varieties, are annually distributed for seed propagation purposes to growers selected by the County Agricultural Instructors.

During the past few years special attention has been paid to the elimination of Virus Diseases from the potato crop, and not only are the home requirements for "seed" now met, but there is developing an export trade in seed certified by the Department of Agriculture in respect of purity, freedom from disease, and grading. (See Virus Diseases; Potato, Virus Diseases of; Potato, Varieties of.)

Beet-Sugar Industry—Following the passage of the Beet Sugar (Subsidy) Act, 1925, a sugar factory was established at Carlow in 1926. The Act provides for the payment of a subsidy on sugar, but not on molasses manufactured in the period 1926-27 to 1935-36. By agreement between the owners of the factory and the Government, the subsidy applies, however, only to a definite quantity of sugar to be manufactured during the ten years. The area devoted to sugar-beet was, on the average of the past five seasons, 14,300 statute acres. The average yields and sugar contents have been as follows:

Year.	*Tons per Statute Acre (Factory Weight).*	*Sugar Content (per Cent.).*
1926	9·1	17·3
1927	7·6	16·7
1928	8·5	17·0
1929	10·9	17·5

Cattle—Of the cattle in the Irish Free State a relatively high proportion is maintained for beef production. Thus, in a recent year for which comparable statistics are available, there were, for each 100 breeding stock, as many as 207 other cattle in this country, as compared with 127 in Great Britain, 89 in France, 81 in Belgium, and 64 in Denmark. The value of the total output of dairy produce, including milk and butter, is estimated to be nearly £14,000,000 per annum, and the value of cattle reared for store and beef purposes is estimated to amount to a like sum. The great majority of the cows are of the Dairy Shorthorn type. The Kerry breed, famous for its hardiness and good milking capacity, is the sole representative of the original cattle of Ireland. It is still kept in the mountainous parts of County Kerry and the Berehaven peninsula of County Cork, within which area only Kerry bulls are used for breeding purposes.

During the last forty years much has been done by means of voluntary schemes to improve the quality of Irish cattle, mainly by the award of premiums to owners of high-class bulls, on condition that these animals are made available at a low fee for the service of cows in the districts in which they are kept. Since the establishment of the Irish Free State this scheme, which was originally instituted by the Royal Dublin Society in 1887, has been greatly extended. The breeds recognized for premium purposes are Shorthorn, Dairy Short-

AGRICULTURE, IRISH FREE STATE (*Continued*)—

horn, Aberdeen Angus, Hereford, Kerry, and Galloway. The number of subsidized bulls standing for service was increased from 764 in 1922 to 2,493 in 1930, of which latter number 622 were Shorthorns and 816 Dairy Shorthorns.

To accelerate the improvement brought about by voluntary effort, the Livestock Breeding Act was passed in 1925. Under this Act it is unlawful to keep or have possession of a bull of the prescribed age without a licence; a licence authorizes the holder to keep the bull referred to therein for the lifetime of the animal. The following classes of bulls which conform to the requisite standard are licensed: (1) save in the Kerry cattle area, pedigree bulls of all breeds, as well as non-pedigree bulls of good Shorthorn type and character; and (2) in the Kerry cattle area, only pure-bred Kerry bulls or non-pedigree bulls of good Kerry type and character. The number of licensed bulls standing for service is now about 23,000.

High-class stock bulls of the Shorthorn, Aberdeen Angus, and Hereford breeds are leased by the Department of Agriculture on very favourable terms to groups of owners of small herds of pedigree cattle, and Dairy Shorthorn stock bulls are similarly made available for Cow-Testing Associations.

The methods already referred to for raising the general standard of cattle have been supplemented since 1906 by measures specially directed to improving the milking capacity of the country's dairy herds. The problem of such improvement has been one of more than ordinary difficulty, as good beef-production qualities have to be combined with good milking qualities, but a good type of dual purpose cow has been established throughout the greater part of the country.

Sheep—The breeding and rearing of sheep is carried on all over the country. The sheep in the hilly districts are of the Cheviot and the Blackface or Scotch Mountain types; Border Leicesters are favoured in Counties Cork and Wexford. The large Roscommons are being gradually replaced in the west by Galways, a smaller breed, for which a flock book was established in 1924. For the poorer and hilly parts of the country the Department of Agriculture supplies annually up to 200 rams of the Blackface and Cheviot breeds at reduced prices.

Pigs—The breeding and rearing of pigs is carried on throughout the country, and particularly by small holders. The type of pig favoured is the long, thrifty, quickly maturing animal of the Large White breed.

As in the case of cattle, the schemes for the improvement of swine mainly take the form of subsidising the sire. Pedigree boars of two breeds are recognized for premium purposes—the Irish Large White (which is identical with the Large White York) for the whole country, and the Large White Ulster for three border counties, namely, Cavan, Monaghan, and Donegal, where pigs of this particular type are kept. The majority of the bacon curers make a voluntary contribution to the cost of the Swine Improvement Scheme by means of a levy of ½d. per pig on their killings, and their contribution provides for the cost of maintaining about 200 premium boars each year. The number of

AGRICULTURE, IRISH FREE STATE (*Continued*)—

premium boars has increased steadily from 412 in 1922 to 1,203 in 1930, and such animals now represent about 60 per cent. of all the boars.

The Livestock Breeding Act, 1925, which has been in operation since autumn, 1925, in so far as it relates to bulls, was applied to boars on October 31, 1930. Under this Act only those boars which, on inspection, have been passed as suitable, may be retained for breeding purposes. The following classes of boars which conform to the requisite standard are licensed: (*a*) throughout the country, pedigree boars of the Irish Large White and Large White Ulster breeds, and of other breeds if used solely for pedigree sows of their respective breeds; (*b*) in any part of the country, non-pedigree boars of the Irish Large White type; and (*c*) in districts bordering on Northern Ireland, non-pedigree boars of the Large White Ulster type.

Horses—Ireland has long been famous for her horses, and though the reputation in which the thoroughbreds and hunters of the Irish Free State is held has been enhanced by their performances in recent years, measures designed to foster the breeding of even better half-bred horses have been adopted.

The State scheme for the improvement of horse breeding, as administered by the County Agricultural Committees, provides for the award of free nominations to registered stallions to mares selected for quality, conformation, and soundness. The register of these stallions is kept by the Department of Agriculture, and entry is restricted to sires of high standard and sound for stud purposes. Thoroughbred, hunter (half-bred), and Irish Draught sires are registered for service in any part of the country; Clydesdales and Shires only for those parts where mares of the type of these breeds are kept. High-class thoroughbred sires purchased by the Department of Agriculture are sold at reduced prices for use in hunter-breeding districts. Half-bred hunter and also Irish Draught sires are supplied on like terms. The Irish Draught horse, for which a stud book was established by the Department in 1919, is a hardy, active animal, with good bone and clean legs, which is suitable to all farm requirements. A mare of this breed when mated with a thoroughbred is likely to produce a weight-carrying hunter, and it is, indeed, to mares of this type that the excellence of Irish hunters is largely attributable. In 1926 the Connemara Pony Society established a stud book for Connemara Ponies, which have long been noted for their hardiness and staying power.

Under the provisions of the Horse Breeding Act, 1918, which came into operation in January, 1920, any stallion (other than a thoroughbred used solely for thoroughbred mares or one used solely for its owner's mares) must be licensed by the Department of Agriculture before it is used for breeding purposes, and only such are licensed as conform to a certain standard and are certified sound for stud purposes.

Poultry—Poultry are kept on the great majority of holdings, and proportionately to a much larger extent on the small farms than on the larger ones. Ducks, turkeys, and geese are kept, in addition to ordinary

AGRICULTURE, IRISH FREE STATE *(Continued)*—

fowls, on many farms. In 1910 the number of poultry of all descriptions was 18,200,000, and the corresponding figure for 1930 was 22,899,000. In no other branch of livestock has there been so notable an increase in recent years. The exports of eggs in shell from the Irish Free State in 1929 amounted to 4,811,000 gt. hd. (a gt. hd. is 10 dozen), valued at £3,219,000. Exports are estimated to amount to about one-half of the total production.

It was in Ireland that subsidized egg-distribution stations were first established as a means of improving general poultry stocks. These stations proved most successful, and many other countries have since adopted this method of poultry improvement. The trap-nesting egg-distribution stations, the first of which were established in 1924, are a development of the former stations. They are designed to ensure, to country poultry keepers, the supply at reasonable prices of hatching eggs from high-class pedigree laying birds which are specially selected for health and vigour, have made good winter and annual records, and have also proved satisfactory as regards size of eggs produced. There are also in operation turkey and goose stations for the distribution of sittings of eggs, and the keeping of high-class turkey cocks at numerous centres throughout the country is also subsidized.

The number of egg-distribution stations (hen and duck) in operation in 1922 was 579, and in that year 49,375 sittings were distributed. In 1929 the number of such stations had increased to 831, and the number of sittings distributed to 91,712. Goose stations increased from 301 in 1922 to 330 in 1929, and turkey stations from 653 in the former year to 1,123 in the latter.

Egg-laying competitions have been held annually at the Munster Institute, Cork, since 1912. There is a steady increase in the number of those who, while engaging in commercial egg production, have achieved success as breeders of pedigree laying stock. This development will be further stimulated by the demand for Irish Free State trap-nested stock which has recently arisen, and which was occasioned by the excellence of the birds, many of them from ordinary egg-distribution stations, exhibited at the World's Poultry Congress, London, 1930.

The Agricultural Produce (Eggs) Act, 1924, provides that eggs cannot be exported by anyone save the proprietors of premises registered for the purpose by the Department of Agriculture, and the eggs must be exported *direct* from those premises. It is a penal offence for any other person to attempt to export eggs, or for any transport or carrying company to accept eggs for export, except from the proprietors of registered stores. In order to obtain registration a shipper must comply with certain well-defined conditions, relating mainly to premises and equipment, laid down by the Act and the Regulations made thereunder. All eggs exported must be tested for quality shortly before despatch from the premises, and, after being tested, the eggs must be graded into one of the four classes prescribed and be packed in standard egg cases which are non-returnable. Work done in the registered premises is frequently inspected, and, as a further check,

AGRICULTURE, IRISH FREE STATE (*Continued*)—

consignments are intercepted in transit, opened, and examined. If a serious defect in testing, grading, or packing is discovered, the case of eggs is forfeited to the State. Where these checks fail to effect improvement, the registration of the premises concerned is cancelled.

The number of eggs exported in 1929 exceeded the exports for the year 1924 by 64½ millions, and, since the inception of legislation in Great Britain requiring all imported eggs to be marked with an indication of the country of origin, Irish Free State eggs have commanded higher prices on the British market than those current for any other marked eggs of similar grade.

Dairying—The annual production of butter is estimated to be approximately 1,500,000 cwts. The export trade in this commodity in the year 1929 amounted to 560,000 cwts. In the same year 808,000 gallons of cream were exported, as well as 94,000 cwts. of condensed and dried milk, and small quantities of cheese and whole milk.

The Irish Free State produces three classes of butter: creamery butter, factory (or blended) butter, and farmers' butter. Of the exports, about 76 per cent. consists of creamery butter, 23 per cent. of factory butter, and only 1 per cent. of farmers' butter. Sweet cream butter is almost universally made in the Irish Free State creameries. The aim is to produce a close, waxy textured, and mild flavoured butter which will keep well.

About the year 1889, Sir Horace Plunkett took the lead in the introduction of the system of Agricultural Co-operation in Ireland, and directed his first efforts towards the organization of farmers in co-operative societies to erect, equip, and work creameries. The Irish Agricultural Organization Society was then established for the promotion of agricultural co-operation. One noteworthy effect of this movement has been the gradual replacement by the creamery system of the older methods of home dairying.

Under the provisions of the Dairy Produce Act, which was passed in 1924, failure to comply with prescribed conditions in regard to cleanliness and order at any place where dairy produce is manufactured for sale is made an offence punishable by heavy penalties. In addition, all creameries, butter factories, and merchants' premises from which butter is exported must be registered under the Act. As a condition precedent to the registration of premises the Department must be satisfied that they comply with the conditions prescribed. In addition, at a creamery, the manager, butter-maker, and persons who carry out the butter-fat tests must possess technical qualifications of a satisfactory standard. All butter consigned from the premises must be packed in standard packages and marked with a registered number for identification purposes. Stringent provisions against misdescriptions or adulteration are contained in the Act. Furthermore, every churning of creamery butter sent through the ports during the export season is examined by Inspectors of the Department of Agriculture, and if the butter does not attain to the high standard of quality prescribed in the Regulations made under the Act, its export is prohibited.

AGRICULTURE, IRISH FREE STATE (*Continued*)—

It has long been realized that a great economic obstacle to the success of the creamery industry in Ireland arose from the fact that no means of regulating the location of creameries existed, with the result that two or three creameries had in some cases been erected in a district where one would suffice. In such cases the efforts of the proprietors of each creamery to draw the available milk supply in the district to their own concern deprived each of them of the reasonable degree of security in the supply of the raw material which is essential to economic stability. This unnecessary competition resulted, moreover, in multiplying the overhead expenses of working, and these expenses had ultimately to be borne by the farmer, who had to accept a lower price for his milk than he should have been able to secure in normal circumstances. In 1927 the Government purchased a considerable number of proprietary creameries with a view to the closing of such as were redundant, and to the transfer of the remainder either to existing creamery societies with which they had hitherto competed or to newly organized co-operative creamery societies. Other privately owned creameries have since been acquired by the Government, and these are to be similarly dealt with. Under the Creamery Act, 1928, no creamery can now be established save under and in accordance with the conditions of a licence from the Minister for Agriculture.

Agricultural Education—The Irish Free State has a very comprehensive system of agricultural education. Each of its twenty-seven administrative counties has a staff of Itinerant Instructors in agriculture, horticulture and bee keeping, poultry keeping and butter making. In the poorer districts, especially along the western seaboard, and in areas in which large estates have been divided into small holdings, the Department of Agriculture has a resident staff of Agricultural Overseers and Assistant Agricultural Overseers who act as advisory officers. The Agricultural Instructors conduct winter classes, which are attended by young farmers. Agricultural courses of a year's duration are provided for young men at colleges in various parts of the country, as well as at the Department's three residential agricultural schools, and at the Albert Agricultural College, Glasnevin, Dublin. This last-mentioned Institution, which was established almost a century ago, was, with its farms, transferred along with the College of Science, Dublin, to University College, Dublin (a constituent College of the National University of Ireland), under the provisions of the University Education (Agriculture and Dairy Science) Act, 1926. The Agricultural Faculty of University College, Dublin, now provides a four years' course in agricultural science. It also affords facilities for the highest type of agricultural research, for which laboratories were recently built and special equipment provided. Trinity College, Dublin (University of Dublin), whose courses in agricultural sciences are co-ordinated with those of University College, Dublin, also grants a degree in agriculture. Under the Act of 1926, to which reference has already been made, a Faculty of Dairy Science was established in University College, Cork—also a constituent College of the National University

AGRICULTURE, IRISH FREE STATE (*Continued*)—

of Ireland. That Faculty has been equipped with a large experimental creamery, laboratories, and a farm, and it provides degree courses of four years' duration in dairy science, as well as courses of instruction in subjects relating to creamery management, which occupy two winter sessions.

The County Instructors in poultry keeping and butter making conduct short courses for young women, and more extensive courses in poultry keeping, dairying, and domestic economy are provided for farmers' daughters at several schools of Rural Domestic Economy. The highest form of instruction in poultry keeping and dairying provided in the Irish Free State for young women is given at the Munster Institute, Cork, which is under the control of the Department of Agriculture.

The Veterinary College of Ireland, Ballsbridge, Dublin, is equipped in accordance with modern requirements for teaching and research, and its courses are designed to meet the needs of students preparing for the examinations of the Royal College of Veterinary Surgeons.

Agricultural Research—Reference has already been made to plant breeding. Research work on silage, animal nutrition, plant diseases, etc., is conducted at the Albert Agricultural College. Dairying problems receive attention in the Faculty of Dairy Science, University College, Cork, and at the Department's Butter Testing Station, Dublin, which is provided with chemical and bacteriological laboratories. The Seed Testing Station, Dublin, which was the first official station to be established in the British Isles (see Seed Control), has done a considerable amount of research in matters appertaining to seeds. In addition to preparing contagious abortion and braxy vaccines for distribution throughout the country, the Department's Veterinary Research Station, Drumcondra, Dublin, conducts research in diseases of farm stock, as does also the Veterinary College of Ireland, Ballsbridge, Dublin.

J. H. H.

AGRICULTURE, NEW ZEALAND—New Zealand is, perhaps, of particular interest to the student of agriculture, because she is almost entirely dependent for her natural wealth on agricultural and pastoral products. In the year 1929, 94 per cent. in value of her exports were in this category, and this figure may be taken as indicative of the general position.

During the last ten years the total value of exports has fluctuated between approximately £43 to about £56 millions per annum, the latter figure being for the year 1928. Further examination shows that the main bulk of such exports are composed of animal products in the form of wool, meat, butter, cheese, hides and pelts, tallow, casings, etc. In 1928 animal products represented nearly 91 per cent. of the value of exports; other produce of the soil, such as *Phormium tenax*, fruit, etc., comprising a further 3 per cent. of the total. In 1928, 84 per cent. of the exports went to Empire countries, and looked at from another angle, New Zealand supplied 18·27 per cent. of the meat,

AGRICULTURE, NEW ZEALAND (*Continued*)—

24·5 per cent. of the butter, and 56·1 per cent. of the cheese imported into Great Britain.

Viewed in this light, attention may well be drawn to the distance, some 13,000 miles, which separates her from her "principal" market, and to her absolute dependence on an efficient service of refrigerator steamers and other auxiliary transport services. Essential as such services are, they constitute a heavy burden on New Zealand producer because of the costs entailed in transporting such overseas. These additional charges give an advantage to British producers and to a lesser extent to foreign producers, such as Denmark and Holland.

In addition, there is the preferential demand of the British consumer for fresh home-produced meat, butter, etc., as against refrigerated produce and, what is less understandable, for Danish butter, which maintains a considerable premium over New Zealand butter. (See Refrigeration.)

Having these economic facts in mind, it can, nevertheless, be truly said that in normal times the average New Zealand farmer can produce and compete in the world's markets at a fair profit. To do this he must necessarily be a low cost producer, and must strive continually to reduce his costs. Fortunately, he has certain major advantages, such as excellent climatic conditions, good soils, a liberal outlook, which is borne out by his appreciation of scientific research, and its application, his whole-hearted support of co-operation, and also active Governmental assistance in the form of scientific, instructive, and grading services.

These statements will serve as a background to an account of New Zealand's agricultural problems, covering what has been achieved and what is in progress.

Before passing to such considerations, opportunity must be taken to draw attention to an event which cannot but have a profound effect on the future development of agricultural science in the Empire in general and in New Zealand in particular. This was the decision of Empire Governments to set up eight Imperial Agricultural Bureaux. The magnificent work of the Bureaux of Entomology and Mycology in their respective sciences had proved so valuable that the principle of extension of such services to other agricultural sciences was unanimously approved and supported. These Bureaux are already functioning, and are financed from funds drawn from every part of the Empire, which funds are controlled by an Empire Executive. This joint action of the Empire has resulted from the strong desire to pull together so that we can all compete more efficiently in the world's markets, with the realization that agriculture, the most important Empire industry, is, unfortunately, the one to which science has been least applied.

The immediate purpose of the Bureaux is to pool all available information on problems common to all parts of the Empire, and to make such information available to research workers, administrators, and other interested workers.

It is hoped that this development will encourage team work, reduce

AGRICULTURE, NEW ZEALAND (*Continued*)—

unnecessary overlapping of work, and facilitate the application of fundamental knowledge, at present lying dormant, to our common problems.

Scientific Services in New Zealand—These may be divided into two categories, one consisting of the agricultural instruction, extension, and grading services, and the other consisting of the research administration which covers both primary and secondary industries.

The first-mentioned services are under the control of the Department of Agriculture, while the latter are controlled by the Department of Scientific and Industrial Research, in close co-operation with the Department of Agriculture. The Department of Scientific and Industrial Research was set up in 1927, and functions through an Executive Council armed with wide powers. In order to obtain the closest measure of co-operation with the industries involved, advisory Research Committees to the Council were appointed to direct and control the investigations decided on. Such a system has proved remarkably successful, and intimate co-operation with other Government Departments, Universities, and other organizations has been invaluable.

The rapid development of a number of major research projects has been facilitated by grants from the Empire Marketing Board, to which special reference will be made below. The value of such assistance cannot be too highly stressed, because work of national importance which could not otherwise have been immediately financed was made possible. There is no question that expenditure of the Board's funds on Imperial research problems will ultimately have a major effect on our national prosperity.

Plant Breeding and Seed Research Station—The Plant Research Station established at Palmerston North in 1928 consists of specialist officers of the Fields Division of the Agricultural Department, good use being made of a grant of £2,000 per annum for five years from the Empire Marketing Board, matched by a similar grant from the Department of Scientific and Industrial Research to provide additional pure research officers to complete the plant research staff.

The aims of the Station are ambitious, its work covering the production of improved strains of disease-free seed of crop plants for local production and export, and also the improvement of herbage plants. (See *D.S.I.R.* and *Dept. of Agric. Ann. Repts.*, 1928, 1929, 1930.)

The work carried out and in progress may be described under the following heads:

1. The improvement of strains and varieties of crop plants in use.
2. Rendering improved strains of above disease-free.
3. The improvement of strains of grasses and clovers in New Zealand pastures.

(1) In New Zealand, as elsewhere, agricultural seeds used commercially are seldom pure, but are rather mixtures of varying numbers of varieties and strains, many of which are inferior in value. For

AGRICULTURE, NEW ZEALAND (*Continued*)—
example, in certain wheats, swedes, and potatoes, these inferior strains or varieties affect the yield and market value of the crops. By purifying such commercial stocks and propagating the superior lines only, considerable increases in yield can be obtained, and the work of pedigreeing is proceeding apace at the Station.

Selections of individual plants considered most true to type are made from a commercial crop. These are hand-threshed and sown in experimental plots, from which, if necessary, further selections are made. Finally, these " nucleus " lines of seed are sown in plots so that if necessary they can be tested against other selections of the same (and of different varieties) for productivity, trueness to type, etc. Finally, they are bulked on a scale sufficiently large for commercial distribution, precautions being taken to avoid contamination by inferior strains by using specially constructed, readily cleaned, threshing plants. Such strains are being produced continuously, and are gradually replacing those at present in use.

In addition to this treatment of existing commercial lines, new strains and varieties from plant breeding stations overseas are being imported and tried out experimentally. Thus, immediate use of the work of other Empire organizations, as the Welsh Plant Breeding Station, the Cambridge Potato Research Station, Scottish Department of Agriculture, is being made, and a large amount of material can thus be handled without an extensive staff.

Once they have been sufficiently increased for commercial distribution a necessary step in such work is the maintenance of pedigree lines in a pure state. To this end, the Station, in conjunction with the Department of Agriculture, has initiated a system of certification whereby pedigreed lines are examined periodically, both during the growing season and subsequent to harvest. Such seed must be grown subject to certain stipulated conditions, and if the product complies with the Station's requirements, it is certified and sold as pedigree seed. As the farmer naturally gets higher prices for certified seed, he readily complies with certification requirements.

(2) A present factor of the greatest economic significance in New Zealand agriculture is plant disease; certain diseases have become so serious as to limit the growing of some crops and, indeed, in certain localities, to render their cultivation impossible. Thus, with potatoes, Virus Diseases have reduced Dominion yields by over 50 per cent. Garden peas can be grown only with difficulty because of the disease known as " Collar " Rot. But the most outstanding example of the effects of disease is Dry Rot in swedes. This has become so serious that our present seeded crop covers one-fifth the acreage that it did twenty years ago. And of this present acreage, Dry Rot takes about 40 per cent., causing an estimated annual loss of £1,500,000. Preliminary investigations tended to stress one significant fact—that most diseases of agricultural crops are carried with (or within) the seed. Further, all crops grown except *Phormium* are of European and/or North American origin, and have all been introduced in seed form, and all diseases present in the crops are of similar origin. It is evident,

AGRICULTURE, NEW ZEALAND (*Continued*)—

therefore, that they have all been introduced with the seed, it having been proved by systematic examination that such diseases are not indigenous. (See Seed, Transmission of Plant Diseases by.)

Therefore it was considered that if pedigree seed obtained as described under (1) were freed from all diseases and bulked under aseptic conditions, complete control of diseases of the crops under treatment would result. The method adopted has proved a simple and efficient means of dealing with the disease problem. For example, the commercial malting barleys of Canterbury (approximately 8,000 acres) are completely free from both Loose and Covered Smuts. These striking results have been achieved by treating small samples of pedigree seed with disinfectants capable of destroying these Smuts. The treatment is so severe that about 75 per cent. of the seed is destroyed. This ensures successful control of disease, but, in addition, acts as a selective agent in the elimination of all but the most vigorous and best producing seeds.

The success attending this work has resulted in the application of similar methods to other diseases. For example, bulk supplies of Smut-free oat and wheat have been produced, and nucleus lines of swedes freed from Dry Rot, peas freed from Collar Rot, and potatoes freed from Virus Diseases have also been produced.

(3) The improvement of strains of grasses and clovers may, perhaps, be regarded as the most important work of the Station. Since the bulk of New Zealand's wealth is represented by sheep and cattle, which, in turn, are produced almost entirely from herbage plants, then the problem of their maintenance and improvement is the most important problem under investigation at the present time.

Largely as a result of the researches of Professor Stapledon and his colleagues at the Welsh Plant Breeding Station, the potentialities of pasture plant improvement are at last receiving the attention they deserve. Briefly, for typical New Zealand pastoral conditions, the objective is the production of strains giving a maximum leaf yield or maximum growth period, with a maximum persistency. Intensive research at the Research Station is being concentrated on the examination of the major grass-land species, including perennial rye-grass, cocksfoot, and red and white clover. The valuable results obtained in the short period of investigation are largely due to the invaluable help obtained from a member of the Welsh Plant Breeding Station Staff. This method of Imperial co-operation is regarded as being of inestimable value, and the principle should be extended and strengthened in other directions.

The results obtained have already clearly demonstrated that the greater part of the perennial rye-grass grown in New Zealand is perennial only in name, although true perennial rye-grass is produced in certain areas. There is no doubt as to its great superiority over the non-permanent strains (*N.Z. J. of Agric.*, July-December, 1929; March-April, 1920; *N.Z. D.S.I.R. Ann. Rept.*, 1929, 1930).

Bulk production of the most desirable strains of seed necessitates a system of seed certification which will ensure the production of

AGRICULTURE, NEW ZEALAND (*Continued*)—

pedigree seed. In addition to the potentialities of improving Dominion grass lands by employing such improved strains, there is the distinct promise that New Zealand will, in the future, be able to offer a supply of better herbage plant seeds to the Empire's granary.

Grass-land Farming—A study of the progress made in production of grass-land products in the last twenty years (see *N.Z. Dept. of Agric. Ann. Rept.*, 1929) will indicate the phenomenal progress made by the New Zealand farmer. For example, the farmer is producing over 40 per cent. more products per acre of occupied area than he did eight years ago. Butter-fat production has doubled during that period, with an increase of only 40 per cent. in the number of cows, and with no increase worth mentioning in the area devoted to dairying. The figures are indicative of the progress made in the application of science by the farmer. Such results have been obtained by the production of more and better grass and subsidiary crops, and their efficient utilization.

The following is a brief description of the means by which this progress has been made:

1. *The Application of Fertilizers*—The soils of New Zealand are, generally speaking, deficient in phosphorus, and with the cumulative removal of this essential element from the soil in the shape of exports of grass-land products it is not surprising that the progressive farmer is endeavouring to make good the loss. As would be expected, an immediate and substantial response is generally obtained from the application of phosphatic fertilizers. It is fortunate that a convenient and readily available source of supply is at hand at Nauru and the Ocean Islands.

The actual acreage top-dressed during the past three years is as follows:

Year.	*Amount of Fertilizers.*	*Area Top-dressed.*
	Tons.	Acres.
1926-7	180,000	1,400,000
1927-8	245,000	1,850,000
1928-9	315,000	2,250,000

Almost the whole of the 315,000 tons used was phosphatic. The area top-dressed in 1928-29 was only 13 per cent. of the sown grass land of the Dominion, and it is estimated that there are not less than 6 million acres from which payable returns from fertilizers could be secured.

In addition to the use of phosphates, the potential returns to be obtained from nitrogen, lime, and potash are at last being realized. The use of nitrogenous fertilizers is rapidly expanding. There is no doubt, however, that a nitrogen response cannot be obtained without adequate use of phosphate, which, in turn, is benefited by nitrogen. In particular areas a remarkable response is obtained from the use of lime.

2. *Improved Strains of Herbage Plants*—This work has already been fully described.

AGRICULTURE, NEW ZEALAND (*Continued*)—

3. *Stock Improvement*—The value and necessity of measuring actual performance of dairy cows by herd testing is being widely realized by the average farmer. In 1926-27 over 170,000 cows were tested, and a substantial increase to 224,000 was recorded in 1927-28. This represents 16·5 per cent. of the total dairy cows for that year. This movement towards stock improvement is subsidized by the Government.

Mineral Contents of Pasture—Systematic investigation into the mineral deficiencies known to exist in Dominion pastures was commenced in 1928, with the assistance of an Empire Marketing Board grant of £2,000 for five years, which was matched by a similar sum from the Department of Scientific and Industrial Research of New Zealand.

The maintenance and carrying capacity of the pastures in New Zealand are subject to certain limiting factors, and the deficiency in the amounts of such minerals as are essential to normal growth and health in such pastures is one of the most serious of these. As yet, comparatively little is known of the fluctuations occurring in the mineral contents of pastures and their significance. In one large central area in the North Island which possesses qualities rendering it eminently suitable for development, mineral deficiency is so serious as to cause stock disease of a widespread nature. In areas where actual disease does not occur it is probable that stock productivity is seriously limited.

The plan of research, which is embraced in an Empire scheme, is based on the proposals of Dr. Orr, Director of the Rowett Research Institute. This extensive Empire scheme will, it is hoped, ensure uniformity in methods and technique so that the results may be comparable, and a solution of the problem facilitated.

Prior to this scheme, a large amount of work by Aston, Reakes, Rigg, and others has contributed to, and will ultimately facilitate, a successful issue. A large volume of published work will be found in the *New Zealand Journal of Agriculture* and the *New Zealand Journal of Science and Technology*.

Noxious Weeds Research—The utilization of large areas of land in New Zealand is severely handicapped, farm costs are increased, and stock and crop losses attributable to the presence of noxious weeds, including ragwort, blackberry, gorse, piri piri, and foxglove.

The Research Council has, with the assistance of an Empire Marketing Board grant, made grants for an organized attack on this problem. Endeavours are being made at the Research Station located at the Cawthron Institute, Nelson, to control them by natural enemies in the form of insect parasites. Promising results are being obtained with Cinnabar Moth in controlling ragwort, but it is too early yet to expect definite results owing to difficulties encountered in acclimatizing the insects to local conditions. An interesting extension of this principle of biological control has been made to insect pests, such as sand flies and mosquitoes (*N.Z. Dept. of Sci. and Ind. Ann. Rept.*, 1928-30). (See Insects, Beneficial.)

AGRICULTURE, NEW ZEALAND (*Continued*)—

Wheat Research Institute—The organization and successful launching of the above is an experiment of considerable interest, because it is a vertical association embracing growers, millers, and bakers.

The Institute, which is located at Christchurch, is contributed to on an agreed basis by the above parties, together with a £1 for £1 subsidy by the Department of Scientific and Industrial Research. The main lines of research are as follows:

1. The breeding and selection of strains of wheat suitable for New Zealand conditions and possessed of the highest qualities for flour and bread-making purposes. (See Wheat, quality of, under Wheat.)
2. Cultural and manurial experimentation on wheat.
3. Certification of proved lines of seed wheat with a view to improving the standard of wheat grown.
4. Chemical, physical, milling, and baking tests, and such investigations of wheat and flour as are likely to benefit growers, millers, bakers, and consumers.

This work is in furtherance of the policy of making the Dominion self-sufficing in respect of its wheat and flour supplies. The necessity of chemical and baking tests for the guidance of growers, millers, and bakers is also a governing factor in the field work.

The influence that research work has excited towards stabilizing the industry and towards bringing together all sections concerned to realize their joint and common responsibilities has been considerable, and of immediate practical value to the industry as a whole (references: *N.Z. D.S.I.R. Ann. Repts.*).

Dairy Research—As the most important single industry in the Dominion, the dairy industry is now receiving the attention it deserves from the research point of view. The Dairy Research Institute set up in 1927 at Palmerston North by the Research Council has chemical and bacteriological laboratories, together with the use of a dairy factory and dairy herds owned by Massey Agricultural College. In addition, arrangements have been made with dairy laboratories at Hamilton and Hawera to undertake co-operative investigations.

New Zealand has striven to raise and standardize the quality of her butter and cheese exports by the organization of efficient grading and inspection, and by the establishment of a Dairy Produce Control Board. In spite of these efforts to give the British consumer the higher quality produce, at no time in history has the industry encountered such serious competition in the world's markets.

The future of the industry depends on the lowering of production costs and the closest attention being paid to maintenance of quality. In cheese, particularly, distance from the market is a serious handicap which has been intensified by profound changes in methods of processing necessitated by the development of the industry. These developments, made without sufficient scientific guidance, because of the lack of fundamental information have resulted in certain major defects. An investigation assisted by an Empire Marketing Board grant is now being actively pursued into the cause and elimination of

AGRICULTURE, NEW ZEALAND (*Continued*)—

such defects. In other directions, such as the determination of a national basis for the grading of milk for butter and cheese manufacture, elimination of waste by the avoidance of butter-fat losses in butter milk, the standardization of starters for separated and whole milk, the effect of nutrition on flavour of milk and cream, statistical examinations of group herd-testing records, etc., intensive work is being carried out.

There is no doubt that the future of the industry will largely depend on the efforts of the Institute, a view which is now being realized by the whole body of producers interested. (*N.Z. D.S.I.R.* and *Dept. of Agric. Ann. Repts.* and Journals; *N.Z. D.S.I.R. Bull.*, No. 9, "The Relative Volumes of High and Low Testing Milk for Cheese-making in New Zealand"; *ibid.*, No. 13, "The Yield of Cheese per Pound Butter Fat"; Dairy Research References: *N.Z. D.S.I.R. Bull.*, No. 31, "Standardised Cheese and Cheese Analysis".)

Pig Industry—The exports of frozen pork from New Zealand to the United Kingdom have gradually increased over the last few years, but in view of the considerable potentialities of extension, development has been comparatively slow. As pointed out in the Imperial Economic Committee's Report No. 12, New Zealand is very favourably placed with suitable climatic conditions, large quantities of dairy by-products now being wasted, etc., to expand this industry.

The New Zealand Department of Scientific and Industrial Research is giving assistance in the investigation of the local problem connected therewith.

Pig recording, centred at Lincoln and Massey Agricultural Colleges, has already served to bring home to the farmer the necessity of utilizing suitable breeds, and of using suitable rations and efficient management. Valuable assistance is being received from pig-recording organizations in the United Kingdom. Work is now proceeding on the study of efficient utilization of pig foods and waste dairy products in the ration, to works processes and transport conditions, and with the production of pigs of suitable size, quality, and conformation for the British market (*N.Z. D.S.I.R. Bull.*, No. 2, "Pig Production and Feeding Trials," *Bull.*, No. 17, "Pig Recording, Bacon Manufacture, and the Pig Industry in New Zealand"; *N.Z. J. of Sci. and Tech.*, various).

Fruit Production Research—A rapid expansion of apple exports from New Zealand has taken place during the last few years, but recent over-production has forced the producer to look to science for assistance in the reduction of costs in many directions. An outstanding example of this assistance was the success obtained in the control of Woolly Aphis by a natural enemy. This outstandingly successful example of biological control saved the fruit farmer from eventual ruin, and taught him the value of the application of scientific results.

Another source of serious loss—unsuitable transportation conditions—has been investigated in detail with the valuable assistance of the Low Temperature Research Station at Cambridge. The method

AGRICULTURE, NEW ZEALAND (*Continued*)—

adopted was to send forward split consignments of apples of known history in refrigerated holds in which the temperature was registered. The other half of the consignment was held in New Zealand under known conditions. The results obtained have thrown considerable light on the vexed problem of ideal transport conditions, and have already resulted in considerable reduction in wastage. (See Refrigeration.)

A later development which must have a considerable effect in the future has been the organization by the Department of Scientific and Industrial Research of a Fruit Research Station located at the Cawthron Institute, Nelson, and assisted by an Empire Marketing Board grant. Here the work on cold storage and transport will be continued, and immediate work will be commenced on the application of the root stock and vegetative propagation research carried out at the East Malling Fruit Research Station (*N.Z. D.S.I.R. Bull.*, Nos. 16 and 23, "Cold Storage Investigations"; also *U.K. D.S.I.R. Ann. Repts.*, 1928, 1929, and 1930; *U.K. D.S.I.R., F.I.B., Special Report*, No. 39, "The Prevention of Wastage in New Zealand Apples").

Agricultural Education—A comprehensive report by a Parliamentary Committee on Educational Reorganization in New Zealand, just published, emphasizes the necessity of the extension of agricultural education by recommending: "That in view of the great importance to the Dominion of our primary industries the curricula of all our schools must include adequate practical institutions in agriculture and allied subjects."

Agricultural Clubs—This movement, based on the successful results obtained in other countries, originated in the heart of the dairy district in Taranaki. It is sponsored by the Departments of Agriculture and Education, in conjunction with the Elementary and High Schools in the district. The farming community has recognized the value of this movement by offering its farms for observation and experimental purposes, and by its general practical encouragement.

There are definite signs that this method of agricultural education is likely to spread to other parts of the country.

Agricultural High Schools—Two residential Agricultural High Schools at Feilding, in the North Island, and Rangiora in the South Island provide three years' theoretical and practical agricultural courses, while many other schools include agricultural subjects in their curriculum. The success of the two above-mentioned schools has so impressed the Education Committee that it has recommended that six further schools be provided at convenient centres.

Agricultural Colleges—At the apex of the Agricultural Educational Institutions stand the Massey Agricultural College, Palmerston North, Wellington, and Canterbury Agricultural College at Lincoln, Canterbury.

Massey Agricultural College—This College was established in 1927, mainly for educational purposes, but provision has been made for research. It is equipped with a modern dairy factory and a farm of 865 acres. The stock carried consists of pure-bred and grade Jersey, Friesian, and Ayrshire dairy cattle, Romney and Southdown

AGRICULTURE, NEW ZEALAND (*Continued*)—
sheep, and Tamworth, Large Black, and Middle White Yorkshire pigs.

Two courses are offered:

(1) Four-year course leading to a Degree of the University of New Zealand.

(2) Two-year courses for College Certificates or Diplomas, and designed to meet the needs of the working dairy farmers' sons.

These courses include training in dairy manufacture, herd-testing, sheep-farming, and wool-classing.

Although its chief activities are educational, facilities have been made available for carrying out research. In conjunction with the Phormium Research Committee of the Department of Scientific and Industrial Research, intensive research on the selection of high quality and maximum fibre-yielding strains of *Phormium*, together with investigations on disease resistance, have been pushed forward (see *Ann. Rept. D.S.I.R.*, 1929-30). Close co-operation with the Dairy Research Institute by placing the College herd and factory at the service of the Institute has had beneficial results. In addition, a certain amount of wool research and pig and pasture research is in progress.

Canterbury Agricultural College—This College was founded in 1880 in the centre of a mixed farming district. It is equipped with extensive farm buildings and a farm of 1,000 acres which is worked on commercial lines. Registered flocks of Border Leicester, English Leicester, Romney, Suffolk, Corriedale, Southdown, and Shropshire sheep are carried, together with herds of pedigree Shorthorn cattle and small herds of pedigree Berkshire, Large Black Tamworth, and Large White pigs.

Three courses of instruction are offered:

(1) Courses leading to a Degree of the New Zealand University;

(2) A course leading to the Diploma of the College, including the following subjects: General Agriculture, Soils and Manures, Wool and Wool Classing, Crop Plants, Farm Management and Economics, etc.;

(3) Short winter course for farmers.

In addition to its teaching activities this college carries out various forms of agricultural research, subsidized to a certain extent by the Department of Scientific and Industrial Research.

The work provided for includes plant breeding, potato improvement, wheat manuring, pig feeding, farm economics, and sheep and wool investigations. The plant breeding work at present affects wheat, oats, cocksfoot, rye-grass, and red clover. Considerable success has been obtained in plant breeding, particularly with wheat, cocksfoot, and rye-grass (reference: *Canterbury Agricultural College Annual Report*).

N. L. W.

AGRICULTURE, NORTHERN IRELAND—The characteristic feature of the agriculture of Northern Ireland is the predominance of the small family farm. Practically all the holdings have been purchased by their occupiers under one or other of the several Land Purchase Acts, and the tenant farmer so typical of English and Scottish agriculture

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

is practically non-existent in Northern Ireland. The following figures show the percentage of holdings of various sizes, and illustrate the dominant part played by the small holding, or, as it is now called, the small family farm:

	Per Cent.
Holdings under 30 acres	68·8
Holdings over 30 and under 50 acres	16·4
Holdings over 50 and under 100 acres	11·1
Holdings over 100 and under 200 acres	2·8
Holdings over 200 acres	0·9

The average size of the farms is 23·5 acres compared with 61·8 acres in Scotland and 66·7 acres in England. The total agricultural area of Northern Ireland, including grazed mountain land, is 3,000,000 acres, and it is interesting to note that in this relatively small area there are considerably more agricultural holdings than in the whole of Scotland.

The farms are worked by the farmer and his family, and there are relatively few paid agricultural labourers employed. The cropping and rotation of the land is in most respects similar to that of Scotland, the usual rotation being oats, roots, oats, hay, grass, grass. After the removal of the hay crop the temporary ley is grazed for two and occasionally for three or four years before being broken up. The area under wheat is only 4,000 acres, the grain being used mainly for home domestic purposes and poultry feeding, whilst the area devoted to barley is usually less than 2,000 acres. Flax, when grown, usually comes in the rotation immediately after the ley oats. The area devoted to this crop varies from 26,000 to 40,000 acres, and of recent years has been diminishing steadily. (See Flax.)

In the western districts, *e.g.*, Fermanagh and parts of Tyrone, where the rainfall is high and tillage operations difficult, the land is mainly under permanent or semi-permanent grass, the tillage being confined to a small area for the raising of potatoes for family use, and relatively small quantities of turnips and oats as a supplement to the winter "keep" for stock.

The following table shows the area and yield per acre of the principal crops in 1928:

Crop.	*Acreage,* 1928.	*Average Yield per Acre.* 1927.	1928.
		Cwts.	Cwts.
Wheat	4,874	19·1	20·1
Oats	307,103	17·8	18·0
Barley	2,032	18·8	19·0
		Tons.	Tons.
Potatoes	155,507	6·9	7·4
Turnips	42,548	16·8	18·0
Mangolds	1,404	15·7	16·0
Hay	448,347	2·0	1·8
		Stones.	Stones.
Flax	37,248	30·3	25·2

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

Oats, it will be observed, occupy one-tenth of the total agricultural area, and potatoes one-twentieth. In fact, the acreage of potatoes is greater than that devoted to this crop in Scotland. Potatoes and flax are the main sale crops, practically the whole of the remainder being consumed on the farm and marketed as animal and animal products. Even in the case of potatoes the proportion of the crop which is marketed is very variable, but does not normally exceed one-third of the total crop. When prices are good the quantity is large, but during seasons of low prices the Ulster farmer can, over the greater part of Northern Ireland, arrange to consume a substantial proportion of his crop on the farm.

A true perspective of the business of farming in Northern Ireland can best be obtained by examining the figures for the value of the "output" of crops and stock and stock products. By output is meant the amount sold off the farms plus the amount consumed on the farms by the human population.

	1925.	1926.	1927.	1928.
CROPS.	£.	£.	£.	£.
Wheat	41,000	55,000	55,000	50,000
Oats	165,000	220,000	480,000	370,000
Barley	15,000	9,000	10,000	13,000
Potatoes	1,280,000	1,980,000	2,123,000	1,275,000
Flax	527,000	444,000	612,000	544,000
Hay and straw ..	180,000	125,000	145,000	175,000
Grass seeds	540,000	560,000	520,000	380,000
Total crops	2,748,000	3,393,000	3,945,000	2,807,000
LIVESTOCK AND LIVESTOCK PRODUCTS.	£.	£.	£.	£.
Cattle	3,496,000	2,590,000	2,295,000	2,095,000
Sheep	595,000	556,000	494,000	535,000
Pigs (pork)	1,399,000	1,055,000	1,312,000	1,682,000
Eggs	2,755,000	2,620,000	2,515,000	2,544,000
Poultry	700,000*	691,000	866,000	869,000
Whole milk	1,500,000†	1,500,000	1,500,000	1,500,000
Milk to creameries ..	433,000	460,000	511,000	515,000
Farmers' butter ..	986,000	820,000	800,000	820,000
Wool	59,000	56,000	75,000	89,000
Total livestock and livestock products	11,923,000	10,348,000	10,368,000	10,649,000
Grand total	14,671,000	13,741,000	14,313,000	13,456,000

Note.—The figures in the table are given to the nearest thousand.

* Revised figure.

† In the absence of data suitable for estimating the sale of whole milk in later years, the figure arrived at in 1925 has been adopted for each of the four years 1925-28.

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

Out of a total agricultural output of approximately 13½ million pounds, slightly more than 10½ million pounds are derived from stock and stock products. The importance of the stock and stock products side of the industry may be gauged from the fact that the value of the output of eggs and poultry is more than £500,000 in excess of the value of the output of all crops. The typical small family farm of Northern Ireland must, therefore, be regarded not as a specialized farm, but as a mixed farm carrying a mixed stock of cattle, sheep, pigs, and poultry, through the medium of which the greater part of the crops are marketed. The land is in a good state of fertility, and the level of crop production compares at least favourably with that of any other part of the British Isles. (See Agriculture, British Isles, Crop and Certain Other Statistics.)

Perhaps the most significant results of the Ulster farmer's policy of marketing his crops as stock and stock products is the fact that he has felt the hardships experienced during the long spell of post-war agricultural depression to a considerably less extent than his colleagues in England and Scotland. This is in marked contrast to the days of last century, when famines in Ireland were by no means rare occurrences.

It is doubtful if any part of the British Isles affords a more striking demonstration of the results from the application of science to agriculture. Examples are numerous, but it will suffice to indicate a few of the more important.

Potatoes—One of the earliest tasks undertaken by the Department of Agriculture and Technical Instruction for Ireland after its formation in 1900 was that of raising the yield per acre from the various crops, the potato crop being singled out for special attention. For the period 1891-1900 the area under the crop was 193,136 acres, and the yield 746,260 tons, equal to 3·9 tons per acre. For the period 1920-29 the area was 159,560 acres, but the average yield had increased to approximately 7 tons per acre. Thus, although the acreage has shrunk by 17 per cent., the total crop has increased by 262,000 tons or 35 per cent. This transformation was principally due to three facts:

(1) An extensive scheme of manurial trials which succeeded in establishing a standard mixture of artificial fertilizers, the advantage of which is so well recognized that the application of the standard mixture of fertilizers may truly be said to be the general practice throughout the country.

(2) The sprouting of sets in boxes before planting and the introduction of improved varieties.

(3) Spraying as a preventive of Potato Blight. It is difficult to overestimate the value of spraying to the farmer in Northern Ireland. Suffice it to say that it is not easy to find a farmer who does not spray every year, and the majority spray their crop three times. (See Potato; and Diseases of Potato.)

The introduction of immune varieties of potatoes has proved a most valuable asset as a means of limiting the spread of wart disease.

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

Farmers have not been slow to realize the advantage of the security offered by immune varieties, and their use in non-scheduled areas is spreading so rapidly that at present immune varieties represent 67 per cent. of the whole crop.

Grass—It has been shown already that livestock is the more important side of the agricultural industry of Northern Ireland, and grass therefore a most important crop. Whilst the climate in Northern Ireland is particularly suited to the growth of grass and the growing season extends well into the late autumn, nevertheless the rainfall, which in the western counties renders possible a hay crop of 3 tons to the acre, made it impossible to leave grass down for any length of time, due mainly to the damp conditions encouraging the rapid spread of rushes. The introduction of wild white clover (*q.v.*), together with the application of phosphatic fertilizers, has brought about a truly remarkable change. The poor, scant, and starved herbage so characteristic of the second and third year leys prior to 1905 are to-day non-existent, and their place is taken by luscious herbage capable of maintaining itself, if properly managed, for an almost indefinite period. This change has encouraged farmers to leave their leys down for four to seven years and even longer, but it has brought with it another problem which bids fair to baffle the plant breeder. So great is the accumulation of fertility from these wild white clover leys that it is almost impossible to secure a standing crop of oats, and as oat straw is a valuable asset for feeding purposes the plant breeder is left with the very difficult problem of breeding a stiffer-strawed oat without losing feeding value in the straw.

Oats—Oats being his only cereal crop, the Ulster farmer has taken a keen interest in its improvement, again with the dominant idea of heavier yields. A great advance was made in the earlier years of this century by improved manuring, but in more recent times he has been looking to an ever-increasing extent to the plant breeder for assistance. The assistance has been forthcoming, new and improved varieties are general, and it has been found possible to map out the province so as to be able to give advice with fair confidence as to the variety or varieties most suited to a particular district.

Livestock—*Cattle*—The improvement which has taken place in Irish cattle during recent years is too well-known to require emphasis. In the main, it has been due to improved breeding methods; and, secondly, to better feeding. The application of science, although not obvious at first sight, has nevertheless been the fundamental factor. All cattle improvement schemes are based on the axiom that like begets like, and that only by mating from the best and eliminating the worst can improvement and progress be made. The scheme for State premiums or subsidies for sires of merit had its origin in Ireland, and was responsible for a considerable improvement in the herds and flocks of the country. Unfortunately, progress was slow, due in part, perhaps, to the fact that, being a cattle-exporting country, there was

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

a continuous tendency for the best cattle to leave the country. However, the premium sire scheme served the extremely valuable purpose of demonstrating to large numbers of farmers what could be accomplished by improved breeding, and induced them to consent readily to giving the State power to eliminate all inferior sires. The coming into operation of the Livestock Breeding Act in 1924 enabled the State to refuse to licence and to insist on the castration of all unsuitable sires. This Act has given a great impetus to the improvement of the general type of cattle and horses in Northern Ireland, and progress during the past six years has proceeded rapidly. The steady increase of our knowledge of the nutrition of farm animals has also had an important bearing on this problem; not only have better methods of feeding resulted in a substantial improvement in the milk yield and quicker maturity of the fattening cattle, pigs, and sheep, but it has had a profound influence in the direction of maintaining the vitality and reducing the losses due to the ravages of disease in the cattle population.

Poultry—No survey of agriculture in Northern Ireland and the progress made would be complete without a reference to poultry. The rapid strides which have been made may be estimated from the fact that the average egg production per bird has increased from 100 in 1908 to 118 in 1925, and the population from 5½ millions in 1923 to almost 9 millions in 1930. Here, again, progress has been due to a combination of factors:

(*a*) Improved breeding methods involving the trap nesting of birds and the elimination of inferior hens for breeding purposes.

(*b*) Improved nutrition.

The hen as a farmyard bird is fast disappearing in Northern Ireland. The poultry plant is becoming a prominent feature on the small farms. The birds are being fed as producers and not treated as scavengers, and a very real effort is being made to apply the results of research on nutrition. (See Poultry Nutrition, under Poultry.)

Agricultural Education and Research—The organization of agricultural education, research, and experimental work in Northern Ireland differs materially from that adopted in England and Scotland, because of the differences in agricultural conditions explained above, and partly because the compactness of the area makes possible a much closer linkage between the various units than is, perhaps, possible in England or Scotland. (See Agricultural Research and Education, Development of; and Agriculture, Scotland.)

County Work and Education—The six counties of Northern Ireland carry a staff of twelve Agricultural Organizers and Instructors, nine Horticultural Instructors, eleven Poultry Instructors, and in addition Agricultural Overseers working in the mountainous areas. The county staffs are not a number of separate units, but are one team working out a definite policy. The various groups of instructors,

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

agricultural, horticultural, and poultry, meet the members of the research staff and the inspectorial staff of the Ministry of Agriculture once or twice a year, and they have before them a draft scheme of experimental work drawn up to fit in with the work of the several research divisions of the Ministry. The proposals are discussed freely in the light of local conditions and difficulties, and, after agreement, become official experiments which each instructor must carry out. Such conferences afford an opportunity of discussing and shaping the policy of the Ministry, and in this way close personal touch is maintained between the county staffs, the Ministry's Inspectorate, and the research workers.

It is the duty of each County Instructor to conduct winter classes at two centres in their area each year. The classes are for farmers' sons and daughters. The age of the students varies from sixteen to thirty years, and the instruction is free. The course lasts for a period of fourteen weeks, and each class meets from 2 p.m, to 6.15 p.m. for two days a week. Each of the County Agricultural Committees awards scholarships tenable at the Greenmount Agricultural and Horticultural College, County Antrim, and usually the best of the winter agricultural class students obtain these scholarships.

In addition to experimental and teaching work, it is part of the duties of the County Instructors to keep in close touch with the Ministry's Livestock Schemes, etc., operating in their area. Thus, for example, the Poultry Instructors are directly responsible for the supervision of approximately 970 official poultry stations which have been established in the six counties.

The Greenmount Agricultural and Horticultural College has resident accommodation for fifty students and there is attached to it a farm of 250 acres. The course of instruction, which is primarily of a practical nature, is of one year's duration, and in all essentials is similar to, if not identical with, the instruction provided by the farm institutes in England. Of the students trained at the Greenmount Agricultural College, approximately 75 per cent. go back to the farm.

Agricultural Education for Girls—For the training of girls two schools—namely, the North-West Agricultural School at Strabane, and the Ulster Dairy School at Cookstown—are available. Both schools are maintained and controlled by the Ministry of Agriculture, and the main object of both is to turn out first-class farmers' wives.

The North-West Agricultural School at Strabane is a junior school, and provides four short courses a year, each of eleven weeks' duration, in dairying, poultry, and domestic science. The school is resident, with a farm of 50 acres attached, and no fees are charged. The girls are drawn from the six counties, and the County Agricultural Committees pay the Ministry 15s. a week for the maintenance of their pupils. Many of the girls come to the schools from the winter classes conducted by the Instructresses in dairying and poultry. There is accommodation for twenty-four girls, that is to say, ninety-six per annum. A few

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

of the girls go on to Cookstown, but over 85 per cent. return to take charge of the dairy and poultry work on their parents' farms.

The Ulster Dairy School is situated at Loughry, a farm of 300 acres, near Cookstown. Provision is made for two types of courses, a junior and a senior. The junior course lasts for three terms, and consists of instruction essentially of a practical nature in dairying, poultry, and domestic science. A fee of 3 guineas a term, which includes instruction and maintenance, is charged. The training of selected girls who desire to take up posts as dairymaids at creameries is continued for a fourth, and, sometimes, a fifth term. Before finishing as a creamery dairymaid, the student must put in a period of six months' training at a selected creamery, and her qualifying examination comes at the end of that period. At the end of the third term of instruction a very careful selection is made, and candidates approved for training as Instructresses continue their course for a further three terms, and before passing their qualifying examination as poultry instructresses must put in one year after completing their course at Cookstown at a commercial poultry farm on the Ministry's approved list. The qualifying examination comes at the end of this period. Girls who have been selected for training as poultry instructresses receive a scholarship from the Ministry sufficient to cover the cost of their one year's training and maintenance on the approved commercial plant. Approximately 50 per cent. of the girls trained at Cookstown return to their parents' farms to take charge of the dairy and poultry work. Thirty per cent. of the girls take up work as creamery dairymaids, poultry managers, and poultry instructresses.

Some idea of the success of these two schools may be gathered from the fact that both have a waiting list, and there is considerable difficulty in meeting the demands made for trained poultry managers.

University Education and Research—University education, research, and experimental work and advisory work, are functions which have all been linked up and are discharged by one staff, the members of which are all permanent Civil Servants on the staff of the Ministry of Agriculture. By arrangement between the Ministry and the Queen's University of Belfast, the staff hold unpaid Professorships, Lectureships, and Assistantships in the University, and are responsible to the University for the teaching work in the Faculty of Agriculture, and to the Ministry for Research and Advisory work, and for certain of the Ministry's technical services.

The scheme does not aim at training students who are returning to farming, but rather a limited number of students to meet the requirements of Northern Ireland for research workers, instructors, and organizers.

With this object in view, two separate University courses, each of four years' duration, are provided by the Faculty of Agriculture—namely, the research or honours course, and the general course. A student in the research or honours course must take the B.Sc. degree in pure science before passing to the agricultural side.

AGRICULTURE, NORTHERN IRELAND (*Continued*)—

The main purpose of the staff is to conduct research and experimental work, and for this purpose six research divisions have been gradually established and developed—namely:

Chemical and Animal Nutrition.
Plant Breeding.
Seed Testing and Plant Diseases.
Animal Diseases.
Crop and Animal Husbandry.
Dairy Bacteriology.

The aim of the research and experimental work is quite definitely applied. It has not as its object the investigation of fundamental or, as they are now called, long range problems, which may or may not in the speculative future be applicable to farming practice. Its deliberate aim is to tackle problems as they exist on the farm, and to find an economic solution applicable to the smallest farms. Indeed, it may be questioned whether that is not the best method of discovery and solving the so-called fundamental problems. It is for this reason that great stress is laid in training research workers on not only a sound training in pure science, but also a sound practical knowledge of the business of farming. Each is of vital importance, and to possess one without the other is to be half-trained. It is the experience in Northern Ireland that if research workers are to be of maximum value to the industry which they serve, they must know at least as much about the practical application of their own subject as the farmers themselves.

G. S. R.

AGRICULTURE, SCOTLAND—General Physical Features—Although Scotland in extent is about half the size of England and Wales (19½ million acres), barely one-fourth of the whole (now under 4,700,000 acres) is cultivated—about two-thirds arable land and one-third permanent grass. There are also about 9 million acres of mountain grazing, in the Highland part of which six acres are required for one sheep.

The reason for the small area of cultivated land is to be found in the relief of the country. Two hill massifs, the Grampians and Southern Uplands, about 100 miles long, cross the country from south-west to north-east at a mean distance of ninety miles. The greater part of the Lowland, cultivated area of Scotland lies between these ranges. Further stretches of lowland lie between the Grampians and the Moray Firth on the north-east and the Southern Uplands and the Solway on the south-west. As between east and west the greater part of the cultivated area lies in the former. The chief river valleys, Tweed, Forth, Tay, Dee and Don, and Spey, are on the east; the Clyde is the only important river on the west. The north-west of Scotland is separated from the rest of the country by the Great Glen, which spans the short distance between the great fiord, Loch Linnhe, on the west, and the inner part of the Moray Firth on the east. The greater part of this area, as of the Hebrides, is only fit for pasturage, but there are stretches of arable land on the east coast of Ross-shire, and again in Caithness and the adjacent Orkney group.

AGRICULTURE, SCOTLAND (*Continued*)—

Climate and Soil—As in England, there is a difference in climate between east and west, the east being drier, which fact goes with level and soil to promote cultivation in that part. The Highlands are high and rocky, but the moist air from the Atlantic at least makes the slopes of the West Highland hills grassy, and generally the nearer the hills are to the western sea, the better the grass. The grass of the Highland hills has been used in modern times mainly for feeding sheep, the grass of the south-west mainly for feeding dairy cows. The specialization has been due in the latter case to the nearness of a large urban market for milk, in the former to the discovery of the West Highland lairds 150 years ago that they might have sheep runs just as the landowners in the Southern Uplands had had for some time before. The north-east of Scotland has a severe climate and harvests may be very late—hence in Aberdeenshire little but oats and turnips are grown, but the inner part of the Moray Firth enjoys a more genial climate, so that the lowlands of Moray and Inverness and Ross are more favoured in their harvests.

As regards soil, though the Lowland parts of Scotland are limited, there is less of the heavy clays of England, except in the Carses of Stirling and Gowrie (Perth), and practically none of the chalk of the south of England. The Old Red Sandstone is the most common formation underlying the cultivated parts of Scotland—in fact, the area between the two mountain massifs is mainly "Old Red" in the northern, and Carboniferous strata in the southern part.

Predominance of Stock Raising—From the foregoing it may be inferred that Scottish agriculture is mainly concerned with stock raising. Hence, its main features may be indicated by certain statistical facts, as, *e.g.*, that the sheep population rises at times to 7½ millions, of which nearly one-half will be ewes; its cattle to 1,200,000, of which 350,000 are cows in milk, a great part of them being dairy cows; that of the 700,000 other cattle (not bulls or cows) there are three groups: (1) two years and above, (2) one year and under two, (3) under one year, and that though at one time the three classes were about equal in numbers, the oldest group is now smaller than either of the other two, that the number of horses used for agricultural purposes has now come down to 125,000, and that even with increases in the last few years pigs do not reach 200,000.

In the arable land oats are the most widely grown crop. At times their acreage has reached 1 million, but is now under 900,000 acres, or about half the area under oats in England and Wales (see Oats), while barley has been grown on 150,000 acres, but is now down to 110,000 acres or thereby, about one-tenth of the corresponding area in England, and wheat remains somewhere near 60,000 acres.

In the green crops, turnips and swedes should be grown on 400,000 acres in good years, and potatoes on 150,000 acres.

The fact that the area under rotation grasses has now reached 1½ million acres, while permanent grass also accounts for the same area, as against 3 million acres of arable land, suggests certain differences

AGRICULTURE, SCOTLAND (*Continued*)—

between English and Scottish agriculture. Put briefly it may be said that while English agriculture is based largely on the Norfolk four-course rotation and permanent grass, the latter covers what is relatively a much smaller area in Scotland, much more grass being grown in the rotation, which is longer than in England, running to five years over a great deal of the country and up to six or seven years as in Aberdeenshire, where the grass may be kept down for three or four years. The greater area of mountain grazing in Scotland, now reaching over 9 million acres, may be said to provide some of the grazing land afforded in England by permanent pasture, while on the other hand of the latter only about one-eighth is used in Scotland for hay, which is obtained mainly from the rotation grasses, of which rather more than one-fourth is cut for hay. Herein we may perhaps see signs of the different evolution of agriculture in the two countries. Perhaps it is not too fanciful to suggest that the English four-course rotation and the permanent grass follow the lines of the old English manor with its "three fields" and its hay meadows. In Scotland, on the other hand, there was a division between infield and outfield; the former was regularly cropped and obtained all the farmyard manure, while the latter was broken up every few years, and after one or two crops had been taken off it was allowed to go back to grass again for a few years. The five- or six-course rotation might perhaps be regarded as a fusion of the infield and outfield—with this big difference, that the grass is now actually sown.

Types of Scottish Farming—Scottish farming falls into four main types connected with definite areas:

(1) Eastern and south-eastern area. Arable farming in which cropping is the main object—stirks or flying stocks of sheep are kept through the winter to eat the roots; the Lothians, the Merse district of Berwickshire, Fife, the greater part of Perth, part of Stirling, and Angus are in this area: perhaps part of Moray and Easter Ross might be added. Wheat, barley, oats, and potatoes are the chief crops.

(2) North-east. The raising and fattening of cattle and to a certain extent sheep is the main business. Turnips and oats, and to a less degree barley, are grown: the rotation grass is down for three or four years. Aberdeen, Banff and Kincardine, and the lowland parts of Inverness and Ross-shire (apart from Easter Ross), belong to this area, and Caithness and Orkney might also be added to it.

(3) West and south-west. This area is given up mainly to dairying, based largely on grass farming—hay is grown on timothy meadows—in parts of the area turnips are also grown for dairy stock. This area includes West Stirling and the lower ground of Argyll, Lanark, Dumbarton, Renfrew, Ayr, and Dumfries and Galloway. In Ayrshire there is some arable farming and early potatoes are an important feature; potato growing has also increased in recent years in Wigtownshire, and Nithsdale, in Dumfriesshire, has some arable farming.

(4) The Southern Uplands and the Grampians. Nearly the whole of the former and a great part of the latter are used for sheep grazing.

AGRICULTURE, SCOTLAND (*Continued*)—

Breeding stocks of Cheviots and Blackface on the former, and mainly Blackface on the latter are carried on large unenclosed farms or sheep runs covering thousands of acres.

The farms in the east and south-east are fairly large, mainly over 250 acres, in the north-east small farms under 150 acres are common, and the same is true of such dairying counties as Ayr and Lanark. There are nominally nearly 76,000 agricultural holdings in Scotland, but a certain number of these are pieces of land used for pastoral or agricultural purposes, as golf clubs grazed by sheep and accommodation land let to graziers and butchers. Hence, the 14,385 holdings owned by their occupiers are probably one-fourth of the total number of farms.

General View of Changes in Scottish Agriculture in the Past Generation—Progress in agriculture may be said to be due to an increase in demand, or to an attempt to meet competitors in a market. The increase in dairy farming is due to a growth of the market for milk, and so far as dairy farming has taken the place of breeding cattle on grazings, as in Galloway, there has been a definite substitution of a more for a less intensive kind of farming. Other changes in farming, however, have been due to economic causes of a different nature. Thus, there is less demand for the flesh of naturally matured sheep on Highland grazings, and again, the ground lost to tillage in the latter part of the nineteenth century has not been regained. Hence, arable farming has been more connected with stock feeding. The economic rent of natural pastures having been lost the farmer has been driven rather into securing the early maturity of his fat stock, now demanded by popular taste, by artificial feeding, and methods more commonly associated with the fattening of bullocks are now used for sheep. Hence, the feeding of stock by artificial foods comes to rival arable cultivation, though fertilisers are now cheaper than feeding stuffs. A greater proportion of the oat crop, too, appears to be eaten by stock than in the past. Further, a greater part of the permanent grass in the dairying counties is now cut for hay, though elsewhere in Scotland hay is mostly taken from the rotation grasses. These developments must be set off against the moderate increase in the yields of the cereal and potato crops. So far as any such increases depend on more liberal applications of artificials one can understand the farmer asking whether it is worth while. Although, theoretically, higher yields may be possible on a given area, it may be cheaper to take in more land, and if more land is being taken in overseas and the produce is brought into the home market something of the same thing happens in another way. And the Scottish farmer finds his economic rent in another shape—in the timothy and other hay, on which the dairy cows are fed, or the turnips eaten by the stirks on Aberdeenshire farms.

The foregoing indications will now be developed in some detail:

Development of Dairying in the West and South-West—The dairy farmers of the south-west of Scotland undoubtedly have a good understanding of the whole art of keeping a dairy farm, including the proper

AGRICULTURE, SCOTLAND (*Continued*)—

feeding of cows, and they usually manage to keep a cow for every two acres. The Galloway farmers, being further from central markets, make a good deal of cheese, which was formerly produced on the Ayrshire farms before the Glasgow market became large enough to take the whole of their milk fresh. The Dumfriesshire farmers, on the other hand, make less cheese, as they find a market for their milk in the Edinburgh district and in the east of Scotland. The increase in dairying in Dumfries and Galloway is indicated by a 50 per cent. increase in cows in these counties since 1890. The uniform standard of good dairy farming in the south-west of Scotland seems to be largely due to the efforts of the West of Scotland Agricultural College at Glasgow, and the Dairy School at Kilmarnock connected with it. The larger farms in Galloway yield enough milk to give work to a cheese-maker, and the influence of the Dairy School is manifest in the training of the cheese-makers.

Milk recording, too, has been practised in the dairy-farming part of Scotland, and perhaps a fifth of the herds are subjected to milk recording according to the rules of the Milk Recording Association, which started in 1903. The improvement in the milk yield of the herds thus controlled is notable, and some Ayrshire cows yield 1,000 gallons of milk in a lactation. The majority of the dairy farmers in Ayrshire and Lanarkshire are, however, working farmers occupying holdings not exceeding 150 acres, and probably they would increase the yield of their cows if they were more careful about the selection of bulls. But as the Ayrshire cow is purely a dairy breed, and as the male calves are usually killed quite young, there is no obvious need for the choice of a bull likely to produce good beef-making progeny, and the transmission of milk-yielding qualities through the bull is perhaps not generally appreciated.

Movements in Stock Raising—It may be of interest to follow a little further the changes in stock raising indicated earlier. Although there are fewer sheep in the north-western counties the total number of sheep, which had fallen at the end of the war, is back at the old figure of 7½ millions. This means that sheep are kept more on Lowland farms. There are, in the Scottish way of speaking, more "park" sheep and fewer "hill" sheep. One would have expected the number of cattle to have gone down, but, according to the statistics, that has not happened. The returns of stock, however, are taken on June 14, and it may be that a fair number of the stores which are fattened on the east coast farms in the winter do not appear in the June returns. This will be true of a part of those imported from Ireland. Certainly, the counties of Argyll, Inverness, and Perth have lost in sheep and the southern and eastern counties have gained.

It was stated earlier that one of the reasons for the decline in hill sheep in the north-western counties was due to the decline in the demand for the mutton from four-year-old wedders. This, however, is not the only reason. The sheep stocks in the Highland counties were usually bound to the ground; the landowner had to take them over at a valuation at the end of a tenancy and resell them to the incoming

AGRICULTURE, SCOTLAND (*Continued*)—

tenant. The valuation usually included a sum for acclimatization value representing the difference between the value of the sheep stock as it was on the ground—acclimatized thereto—and what it would have fetched in a market. This value was always tending to rise, and landlords finding it difficult to get incoming tenants to pay the value had sheep left on their hands, and under these circumstances tended to clear the high ground of sheep and let it for what it was worth as a sporting subject. Further, owing to the lack of winter keep on the mountains of the north it was necessary to send the lambs away to the south to be wintered and brought back; and the south country farmers began to charge more for wintering.

In the south of Scotland, apart from hill flocks of breeding ewes and lambs, which are kept on the hill all the year and get nothing but natural grass except hay in snowstorms, there are a number of low ground farms, on which sheep stock are kept much as bullocks are in the north-east, *i.e.*, turnips are grown to be eaten mainly by the sheep. The so-called half-bred sheep, originally a cross between Border Leicester tups and Cheviot ewes, and now recognized as a distinct breed, are fed on the low ground farms as being a heavier breed than the Cheviots and Blackfaces of which the hill flocks are composed. There seems to have been a considerable increase of this type of farming in Berwickshire. It is probable, too, that more winter stocks of sheep are now fed on the east coast farms instead of bullocks, though as previously stated it cannot be shown that the bullocks have decreased; at the same time, as will be shown shortly, there has been an improvement in the pasture on low ground farms. Further, store cattle have been more difficult to obtain in recent years. This was the reason why the east coast farmers wished to be free to import Canadian stores; but when this was made possible stores came from Canada only for a short time, as the Canadian farmer found that he could sell them readily for fattening in the United States.

The growing difficulty in obtaining store cattle has indeed upset the east coast arable farmer's farm management, for originally the stores were wanted mainly to eat the roots and keep up the fertility of the farm, but if they became dear these objects were attained at too high a price, and the cost of raising crops, which was the main object of east coast arable farming, was raised. The introduction of sheep has, to a certain extent, relieved the situation.

It is worth noting in connection with the changes in the different classes of cattle that whereas in 1928 there were actually more cattle than in 1890, the figures being 1,213,848 as against 1,185,876, (though fewer than in 1891), the decrease in cattle two years old and over is marked, 194,076 as against 263,516.

Increase in Yields of Cereal and Other Crops—A recent inquiry made by Mr. J. R. Campbell (formerly of the Irish Department of Agriculture and Technical Instruction) at the instance of the Scottish Department, into the effect upon farming practice of the scientific training given by the Agricultural Colleges, has brought out some

AGRICULTURE, SCOTLAND (*Continued*)—

results measured by increased yields of field crops ("Agricultural Education in Scotland," 1927).

Thus, comparing yields in 1886-90 with 1921-25, Mr. Campbell finds that the yield of wheat has increased from 19·1 to 21·3 cwts., barley from 16·8 to 17·4 cwts., oats from 13 to 14·4 cwts. per acre, potatoes from 5·7 to 6·7 tons, turnips and swedes from 15·4 to 16·8 tons, rotation hay from 31 to 31·7 cwts., and meadow hay from 29·7 to 30·8 cwts. per acre.

Wheat had got down to its present acreage by 1890, but the area under barley has decreased considerably since that time, so that presumably the average yield should be higher.

Mr. Campbell thinks that the increases do represent the effect of increased knowledge "of the advantages of improved varieties of crops and grass seed" and of scientific manuring, these being the matters on which the extension staff of the Colleges have concentrated.

As regards oats, Mr. Campbell finds it difficult to say to which of the two influences the improvement is mainly due. "The most general opinion is that improved forms of the older varieties are most productive where the soil is poor, and the newer varieties where the soil is good or in a high state of cultivation."

"Much more definite are the results due to improved grass seed mixtures, and particularly to the use of wild white clover. Before the introduction of this plant, the third year rotation pastures (rendered necessary as a means of avoiding finger and toe in the root crop) were often very poor and unprofitable, and nowhere more so than on the lighter upland soils. (In spite of heavy seeding and applications of bone meal and other fertilizers the common bent grass tended to supplant the better grasses and to trouble the succeeding crop of oats.) By the introduction of wild white clover, however, very remarkable changes have taken place where the land is well cultivated and suitably manured. In such cases the third year's grazing, instead of being inferior to the second, is now usually better, and the making of permanent pasture—formerly a costly, difficult, and lengthy process—has now become comparatively easy. . . . Some rotation pastures on land whose herbage I had occasion to study closely some thirty years ago are, I am assured, carrying double the stock they formerly did." Mr. Campbell then refers to tables which show that in the Laurencekirk district of Kincardine and in the Cupar district of Fife between 1912-14 and 1925, sheep stock had doubled in the former and increased by nearly 50 per cent. in the latter case, with little difference in the number of cattle or in the acreage under crops and grass—in fact, a decrease in the area under permanent grass.

Changes in Potato Crop—The potato has been grown as a field crop in Scotland for 100 years, and about 140,000 to 150,000 acres of agricultural land are planted with it yearly. The greater part of the Scotch "ware" crop is sold in Scotland, but there is a considerable trade of long standing in "seed" exported to England. Main crop potatoes are grown chiefly in the Lothians, Fife, Angus, East Perth,

AGRICULTURE, SCOTLAND (*Continued*)—

Easter Ross, and Dumfries, earlies in Ayrshire and Wigtown. New varieties of potato are always being put on the market. A Scottish breeder named Finlay struck out a new line in potato breeding in the nineties by producing new varieties by crossing, and some of his varieties have been grown over large areas in Scotland.

It is doubtful whether any great increase in yield has taken place in the last generation. Some varieties yield as much as 14 tons to the acre on suitable soil and in a good year, but for most kinds 9 tons is a good yield.

In recent years breeders have turned their attention mainly to producing varieties immune from Wart Disease (*Synchitrium endobioticum*), and Scottish growers, particularly those exporting seed to England, have had to plant varieties certified as immune. It is sometimes alleged that such varieties do not yield tubers the most palatable as food, but breeding for "quality" is not an easy thing to differentiate.

In the foregoing it has been assumed that improvements in the yield of potatoes should be sought for in the appearance of new varieties, but if the varieties have been bred mainly for the purpose of securing immunity from disease, other results must not necessarily follow. And it is generally believed that varieties of potatoes tend to degenerate, although some of the older varieties are as prolific as more recent ones. And enhanced yields are no doubt due partly to improvements in the technique of cultivation.

Progress among the Scottish Crofters—One class of Scottish farmer —namely, the crofter—has certainly made progress in the past thirty years. He is normally the tenant (though in recent years he may have had to buy his holding) of a small holding in the counties of Argyll, Inverness, Ross and Cromarty, Sutherland, Caithness, Orkney and Shetland. The crofters are mainly breeders of cattle and sheep. In the parts of the mainland counties bordering on the Moray Firth and in Orkney the crofter is not unlike the small farmer in Aberdeenshire, but in the Hebrides, Shetland, and the north-western parts of the mainland he is usually a member of a group holding arable land and perhaps outrun in severalty and also having a share in a common grazing. The two classes, however, are united in virtue of a special statutory tenure which they share, giving them the right to a judicial rent, security of tenure, and a right to obtain compensation for permanent improvements executed by themselves or their predecessors in the holding, the buildings having in fact usually been provided in this way. Crofters holding under this tenure are also common on the island of Arran.

A great improvement in the stock on crofters' holdings has been noticeable in recent years. This is largely due to the efforts of the Congested Districts Board and its successor, the Board of Agriculture, who have introduced stallions, bulls, and rams of better strains into the crofting districts. The crops grown by the crofters are mainly oats and potatoes; in some districts turnips are also grown. The North

AGRICULTURE, SCOTLAND (*Continued*)—

of Scotland and West of Scotland Colleges of Agriculture may claim some credit for improvements in agricultural practice, and not least in the keeping of poultry by crofters. A considerable number of sheep farms in the Hebrides and parts of the mainland have also been made available for land settlement and handed over to groups of crofters, to whom the greater part of the existing sheep stocks are transferred, the greater part of the purchase price being advanced to them. The new settlers usually breed cattle on the farms and also cultivate some arable land.

Changes in Labour and Increased Use of Machinery—Another aspect of Scottish agriculture is connected with human labour, horses, and machinery. The labourers in 1928 numbered 117,300, comprising 100,563 regular and 16,737 casual labourers. Among the latter there were 7,416, but among the former only 18,957 women.

The number of shepherds fell from 10,000 to 9,000 between the years 1881 to 1911; other regular male farm servants decreased from 91,801 in 1881 to 75,000 in 1921.

The number of horses used in agriculture fell from 141,000 in 1890 to 125,000 in 1928.

The decline in horsemen and horses in the period is no doubt connected with the decline in arable acreage. As, prior to the introduction of the tractor, field machinery was drawn mainly by horse power, the increased use of such machinery may account for some decline in the use of human labour, but less in the case of horses. In the last thirty years it is not so much a case of new field machinery being introduced into Scotland as of such machinery being more generally used on smaller farms. The combined reaping and binding machine is said to be the most conspicuous instance of this. According to the Census of Production taken in 1925, there were in use in Scottish Agriculture 1,691 tractors, including 1,400 for field operations and 291 for stationary work. The eastern and western and south-western districts had the greater number of tractors.

In fixed or portable engines there was a great increase (in 1925) in oil or petrol engines, which numbered 11,137 and a drop in steam engines to 401 as against 2,036 in 1908.

Co-operative Marketing—Certain attempts to better marketing of produce have been made by Scottish farmers in recent years. The most important of these is the Milk Agency, whose members are drawn mainly from the dairy farmers of the west and south-west of Scotland from Falkirk to Wigtown, who send their milk to the Clyde valley market. In Ayrshire and other districts the dairy farmers had already formed co-operative associations, owning milk depôts, for handling and transporting milk and making cheese. Most of these societies are in the Agency, which has more than 2,000 members. Prior to the formation of the Agency there had been an attempt by the Scottish National Farmers' Union to fix prices by collective bargaining with wholesale dealers, but these arrangements had not been generally respected. The Milk Agency

AGRICULTURE, SCOTLAND (*Continued*)—

obtained an undertaking from all its members that they would dispose of their milk only through the Agency. Having secured thereby control of large supplies, the Milk Agency undertook to ensure a defined price for its members. Its great problem was to dispose of milk that was surplus to the amount which from week to week could be sold at the highest price for fresh milk in the Glasgow and neighbouring area. The Agency, which started in the autumn of 1928, was able at an early date to reach a friendly arrangement with the Scottish Co-operative Wholesale Society and with several wholesale distributive firms. Some of the retail co-operative societies, however, stood out of the arrangement, and through their independent action it was found impossible to adhere to the prices settled for the spring of 1929. Thus, the Agency found itself obliged to find considerable sums of money to make the payments agreed on to its members for milk sold at lower prices. Changes in method and procedure had thereafter to be made, but on the whole the members have adhered to the Agency.

Agricultural Education and Research—The growth of a system of agricultural education with its appropriate organs in Scotland during the past generation is an interesting story. There are three agricultural colleges: Glasgow and West of Scotland, founded in 1899; Edinburgh and East of Scotland, 1901-2; North of Scotland College of Agriculture, Aberdeen, 1904. These are the main centres of agricultural education in Scotland, each having a definite geographical area. Each of these areas is largely the scene of a uniform type of agriculture according to the distribution already indicated—stock raising in the north-east and north, cropping in the east and south-east, and dairying in the south-west. The colleges are placed in three of the four seats of universities, and since a degree of B.Sc. in Agriculture is given at all three universities there is a certain co-ordination with the teaching of the central classes at the Colleges. Further, in the case of Edinburgh and Aberdeen the colleges may be said to have taken over the previously existing nucleus of a system of agricultural education. In Glasgow the predecessor of the College was rather a Department of the Technical College; in Edinburgh, too, evening agricultural classes had been held at the Heriot Watt College.

The system now in being may be said to have been the effect of a union of local initiative and guidance and supervision from the central government. Thus, the organization of an Agricultural Department in the Glasgow Technical College was largely due to the initiative, imagination, and persistence of Professor R. Patrick Wright, who early saw the need of combining instruction at a central institution with an extension over the whole area of the west and south-west of Scotland. Lectures in dairying were a prominent part in the latter, as was natural in a dairying area, and the development was made easier by the existence of a dairy school at Kilmarnock, afterwards closely associated with the West of Scotland College.

In Edinburgh University there had been a chair of agriculture for 100 years, and it was not unnatural that a school of rural economy had

AGRICULTURE, SCOTLAND (*Continued*)—
grown up in the University during Professor Wallace's long tenure of office. The Heriot Watt College, Veterinary College, and Botanic Garden all had a share in the teaching. The founding of the College was due to a feeling that these scattered strands should be brought together.

In the University of Aberdeen the work of Mr. T. Jamieson, the Lecturer in Agriculture and a well-known chemist, paved the way to a more elaborate provision. The establishment of the degree of B.Sc. in Agriculture led to the formation of an Agricultural Department in the University, and in due time the College was founded to carry agricultural education more thoroughly into the wide and scattered area of the north and north-west of Scotland.

This fuller conception of the work of an agricultural college was due largely to the stimulus first of the Board (now Ministry) of Agriculture, and then of the Scottish Education Department under Sir Henry Craik and Sir John Struthers.

The Colleges, working with the Universities, have been brought into association with the various schemes of agricultural research that have been promoted in recent years. In Aberdeen, the Rowett, a separate institution for research into animal nutrition, has also been set up. The formation of a Plant Breeding Station near Edinburgh was due largely to the initiative of the agricultural community in Scotland.

H. M. C.

AGRICULTURE, UNION OF SOUTH AFRICA—Introduction—Though the Union of South Africa is generally thought of in terms of gold and diamonds and other metals and minerals, agriculture is actually the most important industry. The early settlers in the Cape in the seventeenth century were obliged to provide for their own needs and for the needs of passing ships for fresh vegetables and meat. This was the commencement from which European agriculture in South Africa developed gradually. Stock breeding, the culture of the vine, wheat growing, and sheep farming formed the early beginnings of the staple industry of the country.

Prior to 1910, the four colonies administered their agricultural affairs separately. By the Act of Union, Parliament had the power to administer agricultural affairs itself, or to delegate the whole or any part of the work to the Provinces. The organization of the Union Department of Agriculture was taken in hand soon after the passing of the Act. The Department is modelled largely on the lines of the Department of Agriculture of the United States of America. The Minister of Agriculture is the head of the Department, and is responsible to Parliament for the policy and acts of his Department; the permanent head of the Department is the Secretary, who is responsible to the Minister for the work of the Department, and has the services of an Under Secretary. The functions of the Department are administrative, regulatory, and the organization of research and extension. Apart from the general administrative staff, the main subdivisions of the Department are:

AGRICULTURE, UNION OF SOUTH AFRICA (*Continued*)—

1. Animal Industry and Veterinary Services.
2. Plant Industry.
3. Chemistry.
4. Agricultural Economics and Markets (including Co-operation).
5. Agricultural Education and Extension.
6. The Stellenbosch-Elsenburg College of Agriculture of the University of Stellenbosch, responsible for the agriculture of the winter-rainfall area.

The Onderstepoort Research Station of the Division of Veterinary Services has been selected as the central station for veterinary research in the British Commonwealth of Nations.

Under the Division of Agricultural Education and Extension fall the Agricultural Schools at Potchefstroom (Transvaal), Glen (Free State), Grootfontein (Middelburg, Cape), and Cedara (Natal), where one-year agricultural courses are given; there is a number of extension officers stationed in various districts surrounding these centres of education.

The Stellenbosch-Elsenburg College of Agriculture of the University of Stellenbosch, and the Faculty of Agriculture of the Transvaal University, Pretoria, supply higher training, leading to academic degrees in agriculture. There are various substations for experimental and demonstration purposes in various parts of the country.

Apart from the administrative, general, and temporary staff, there are more than four hundred scientific and technical officers, qualified in various branches of agricultural science, in the service of the Department, giving attention mainly to regulatory, research, and educational activities in the various phases of the agricultural industry.

There are in each of the four Provinces of the Union numbers of agricultural societies and farmers' associations—about four hundred in all—having as members a great many of the most influential and progressive farmers. An important function of agricultural societies is the promotion of the various agricultural shows, of which sixty or more are held annually throughout the country. Most of the societies are affiliated to the Provincial Agricultural Unions, which select ten delegates or representatives to form the "South African Agricultural Union"; this meets annually to discuss agricultural matters. The Executive Committee of the South African Agricultural Union forms an Agricultural Advisory Board to advise the Minister on matters relating to agriculture.

Various specialized phases of agriculture have special separate organizations, the most important of these being: South African Citrus Exchange, South African Deciduous Fruit Exchange, the National Wool Growers' Association, the South African Poultry Association, and various cattle societies, and societies dealing with other agricultural products.

Co-operative undertakings in the Union may briefly be grouped under two heads—namely, Agricultural Co-operatives or Producers' Organizations; and Trading or Consumers' Organizations. The former are established on the basis of limited, or unlimited, financial responsi-

AGRICULTURE, UNION OF SOUTH AFRICA (*Continued*)—

bility to their members for the purpose, chiefly, of disposing of their products collectively, and to provide members with farm requirements such as agricultural machinery, implements, pure-bred livestock, etc. Membership is confined to the producer of agricultural products—namely, the farmer. In June, 1930, there were four hundred and forty-two Co-operative Societies registered in the Union, having a membership of 62,577.

In 1912, the Land and Agricultural Bank of South Africa was established for the purpose of financing Co-operative Societies, and of making financial loans to farmers for purchasing land, fencing, constructing dipping tanks, and building silos. Since 1912 over £8,000,000 has been advanced to farmers for these essential services. Under the Agricultural Credit Act of 1926, the Land Bank was further empowered to loan funds to Agricultural Credit Societies.

Land Settlement—Provision has been made through various Land Settlement Acts since 1912 for facilitating the purchase, subdivision, and disposal of private and company land for settlement purposes. At March 31, 1926, there were over 11,000 farmers on the books of the Department of Lands. A capital sum of over £4,000,000 was due to the Government for land sold, for advances made to settlers, and for advances in connection with land settlement.

Agricultural Publications—The Department of Agriculture has an agricultural library at Pretoria containing about 10,000 books on agriculture, and a large number of current agricultural publications and periodicals for the use of Departmental officers and farmers. The Department publishes a monthly official organ, *Farming in South Africa*, and a monthly publication, *Crops and Markets*, both of which reach a large number of farmers throughout the country. The Department also supplies the Press of the country with a weekly agricultural news service. In addition, the country is served by a number of excellent private weekly and monthly papers, such as, amongst others, *Die Landbouweekblad, The Farmers' Weekly, The Farmers' Advocate*. Various publications, such as the Official Year Books of the Union of South Africa, the Handbook for Farmers (1929) by the Department of Agriculture, the South and East African Year Book, are rich mines of information and guidance in regard to South African agriculture.

Economics—Agriculture in South Africa is only on the threshold of its development. Rich sources in every direction await further exploration and profitable utilization; by these means the welfare and prosperity of South Africa may be further stimulated and accelerated.

Over 42 per cent. of the European population is rural, and of the total area of 300,000,000 acres of land in 1926, 205,000,000 acres were occupied as farm land. It is estimated that about 3,000,000 acres of the total area of the Union are irrigable. A number of individual and State-organized schemes exist, including the Hartebeestpoort Dam, Lake Mentz, and Tarka.

AGRICULTURE, UNION OF SOUTH AFRICA (*Continued*)—

According to the 1927 Census there were 93,000 occupied farms in the Union. Fifty-one per cent. of the number of occupied farms and agricultural holdings are less than 1,000 acres in extent, but comprise less than 10 per cent. of the total farm area. In the Cape Province 63 per cent. of the total farm area is composed of farms of more than 10,000 acres. The total agricultural valuation of land and improvements, machinery and implements, and livestock exceeds £500,000,000.

An estimate of the value of agricultural production during the 1925-26 crop year is £70,000,000, on a basis of market values, or £57,000,000 on average farm values, while that from mines (1926) amounts to £59,000,000, and from industry (1925-26) to £92,000,000, of which about £30,000,000 represents farm products manufactured for consumption.

Soil Regions and Farming Types—Topography, climate, soil, and economic conditions are amongst the main factors which have influenced the development of the principal types of farming in various sections of the country. The subtropical and temperate characters of the climate make it possible to produce any agricultural product in almost any part of the country, but owing to other conditions the production of the chief agricultural products on a large scale is definitely limited to various sections of the country. On almost every farm a number of poultry and fruit trees may be found, although farming in these directions may not be on a commercial scale. Around the urban centres vegetable growing and truck farming are carried out on an extensive scale.

LIVESTOCK AND LIVESTOCK PRODUCTS—According to the preliminary Census returns, the outside number of cattle in the Union on August 31, 1929, was as follows: European owned, 5,264,355; native owned (including native cattle on European farms), 5,253,644.

The solution of the cattle problem has occupied the attention of the Department of Agriculture for many years. The Government and private owners are occupied in endeavouring to improve the cattle industry. The problem abounds with difficulties, not the least of which is the large number of native-owned cattle. Further, it cannot be expected that there will be any general movement towards the improvement of the beef cattle unless there is reasonable certainty of remunerative markets.

Veterinary Administration and Control of Stock Diseases—Much progress can be reported in the eradication of diseases as the result of a campaign controlled by the State. South Africa has so far been successful in preventing the introduction of certain formidable diseases, such as the Foot-and-Mouth disease, but other diseases, unfortunately, exist. Much work has been done latterly in the eradication of Scab, and a great deal has been done in regard to Tuberculosis, Mange in equines, Epizootic Lymphangitis, Glanders, Anthrax, and Rabies. In addition to the issuing of Horse-Sickness serum and Virus-dipping materials, and doses of Government wireworm remedy,

AGRICULTURE, UNION OF SOUTH AFRICA (*Continued*)—

Anthrax Spore vaccine, Black Quarter vaccine, Blue Tongue vaccine, Red Water and Gall-Sickness vaccine, Contagious Abortion vaccine, Foul Typhoid and Foul Pox vaccines, and Paratyphoid vaccine for calves are issued regularly.

Pathological work is carried out on a large scale. Other matters falling within the sphere of veterinary administration comprise surgery, obstetrics, anatomy, physiology, and toxicology in connection with animals, as well as chemical investigation.

Sheep and Wool—The Department's estimate of the number of sheep in the Union at June 30, 1930, is: wooled, 41,651,705; other, 5,470,890. The wool export for the year was: grease, 288,114,112 lbs., valued at £10,711,711; scoured, 7,293, 991 lbs., valued at £586,673.

In almost every area of the Union there are farms where sheep would do well. At the present time the Karroo region and the Transkei, the South-West Rand, Free State, and the High Veld of the Transvaal are the main sheep areas. The Merino is the principal type of sheep. (See Wool.)

Goats and Mohair—South Africa produces more than half of the world's consumption of mohair. There has latterly, however, been an enormous falling off in the value of mohair, and a Committee has been appointed with a view to seeing what can be done for the industry.

The Dairy Industry—For a number of years the dairy industry languished. Latterly, a governmental enquiry by the Board of Trade and Industries was carried out in regard to the industry, resulting in the passing by the Legislature of the Dairy Industry Control Act, by which means the industry is likely to be built up into one of the major industries of the Union.

The production of butter has increased from 11,000,000 lbs. in 1910 to 24,000,000 lbs. in 1926. The fact that New Zealand, with less than twice as many cows in milk as South Africa, produces almost nine times as much dairy products indicates the great scope for the development of dairying in South Africa. (See Agriculture, New Zealand.)

Poultry—The poultry industry has made great strides in the export of eggs since 1920. In 1911, 2,700 cases of eggs of 30 dozen each were exported, while in the year ending June, 1930, the exports were 53,176,024 eggs. The Co-operative Egg Circles have given great impetus to the production of a better standardized product for the overseas market. The development in the poultry industry in the Union has been little short of phenomenal.

Hides and Skins—For a number of years South African hides and skins have been marketed in the northern hemisphere, the hides being used largely in the sole leather trade and the skins in allied trades. The skins from "Cape" goats have long been known in their made-up form of "Cape" gloves.

With keenness of competition, however, an element developed in the trade which was not to its ultimate good. In 1929, the Government, after exhaustive enquiries into the hide and skin trade,

AGRICULTURE, UNION OF SOUTH AFRICA (*Continued*)—
issued governmental regulations which it is expected will go a long way towards placing South African hides and skins on the high plane which they formerly occupied.

CROPS—Maize—Maize is one of the special crops of South Africa; there were 5,000,000 acres of land under maize in 1926-27 which produced over 36,000,000 bags of grain. Most of the maize is grown in what is called the Maize Triangle—an area comprising the North-Eastern Free State, the Natal High Veld, and Transvaal High Veld. The average production is 4 bags (200 lbs. each) per acre. Maize growing has made excellent progress since the Union, the production having increased from 8,500,000 bags in 1911 to over 24,000,000 bags in 1924-25. Considerable progress has been made with breeding research, and it is evident that with the low yields and the general tendency to lower prices such work is greatly needed.

Wheat—Wheat is not a major crop in South Africa to the same extent as maize, the country growing only about one-third of the quantity required for its own consumption. The production of wheat per acre is 11·6 bags (of 200 lbs. each). Considerable experimental research work has been carried out latterly for the various centres, particularly in connection with the Malmesbury Experimental Station.

In addition to maize and wheat, oats and barley and fodder crops—such as lucerne, teff, and manna—are grown.

Sugar—The sugar industry in Natal provides for all the country's needs, and is in a position to export increasingly larger supplies of "cargo" sugar to the United Kingdom. For many years difficulties were known to exist in the industry. Following upon an investigation by the Board of Trade and Industries and the adoption of its recommendations, these difficulties have been overcome, and planters and importers are enjoying the benefit today. The production of sugar in 1922 totalled 164,000 tons. The production for the year 1930 is likely to be over 300,000 tons. (See Sugar-Cane.)

Field Husbandry—The projects carried out at the Division's Experimental Station, and in co-operation with other divisions, are directed by the Field Husbandry Sections, and deal with the principal Field Husbandry problems. Investigation into soil fertility, irrigation, crop rotation, varietal trials, crop improvement, crop adaptation, cultural practices, etc., are given particular attention.

The following have engaged the attention of the Division for some time: Cotton, tobacco, coffee, fibre crops and hops, maize, sorghums, potatoes, winter cereals, legumes and fodder crops.

The Government Entomologists have devoted much time to apiculture, and much work has been done on the Eucalyptus Snout beetle; citrus insects, such as False Codling Moth; *Colasposama fulgidum*; Mealie Bug; Scale insects; Fruit Flies; tobacco pests; Sheep Blowflies; Maize Stalk Borers; Locusts; Termites and various insects.

Fruit—The fruit industry, deciduous as well as citrus, has made great progress in recent years. The fruits grown comprise peaches,

AGRICULTURE, UNION OF SOUTH AFRICA (*Continued*)—

pears, plums, apricots, nectarines, apples, grapes, litchies, oranges, mandarines, grapefruit, bananas, pineapples, pawpaws, and mangoes. Large quantities of fruit are exported overseas. The industry has great potentialities, and in the near future exports to European countries will undoubtedly increase considerably. (See Refrigeration.)

Viticulture—Large quantities of wines and brandy are made annually, and the Department of Agriculture, in collaboration with the Board of Trade and Industries, have done much work in the interests of the industry. The industry is more or less controlled by the Co-operative Wine Growers' Association (appointed by statute).

Low Temperature Research—The Government physicist, acting largely in collaboration with the Low Temperature Station at Cambridge, continues to carry out experimental and research work with fruit. (See Refrigeration.)

In a short review such as the above, it is impossible to cover the many lines of agriculture which are being followed in South Africa in detail. Suffice it to say that as a result of the work of the Agricultural Department, coupled with that of individual farmers, agriculture in South Africa is likely to continue to achieve developments as great as those made in the past twenty years. Annually increasing quantities of agricultural produce are marketed overseas, and every endeavour, both private and governmental, is made to ensure the highest standard of quality; South Africa is thus rapidly becoming known to a wide circle of consumers of her products in the northern hemisphere.

BIBLIOGRAPHY.—*South African Year Book*; "South Africa and Science"; "Farming in South Africa"; Annual Report of the Secretary for Agriculture; Annual Report of the Director of the Land Bank.

A. T. B.

AGRICULTURE, WALES—**Introduction**—The agriculture of Wales is governed largely by the existence of the mountains and the proximity of the western seaboard. The following table, taken from the Report of the Welsh Land Commission, shows the large proportion of upland and mountain:

TABLE 1.

Altitudes (Ft.).	*Area of Contours.*		*Proportion per Cent. of Each Group of Areas.*
	Acres.	*Square Miles.*	
From 0 to 50	249,269	389·4	4·9
,, 50 ,, 100	183,440	286·7	3·6
,, 100 ,, 500	1,665,023	2,601·5	32·5
,, 500 ,, 1,000	1,638,859	2,560·4	31·9
,, 1,000 ,, 1,500	1,029,198	1,608·2	20·1
,, 1,500 ,, 2,000	309,576	483·6	6·04
,, 2,000 upwards	47,885	74·7	0·9
	5,123,250	8,004·5	100·0

AGRICULTURE, WALES (*Continued*)—

The rainfall is heavy—up to nearly 200 inches in one or two of the mountain districts—and a large proportion of the country has an average of over 40 inches, though cultivation is not common where the rainfall exceeds 60 inches. Very few parts of Wales are more than forty miles from the west coast, so that, except in the mountains, the winters are mild, comparing not unfavourably with those of Cornwall and Devon. The wet, mild climate naturally favours grass farming rather than arable cultivation, and, along with the existence of so much rough upland grazing, accounts for the position which Wales has always held as a stock-rearing country. The proportion of tilled land (that is, arable land excluding clover and rotation grasses) is now only about 12 per cent. of the total acreage of crops and grass; in contrast with this, some of the eastern counties of England, where the rainfall is low, have over 60 per cent.

Soils—A detailed soil survey of the whole Principality is being made by Robinson and his colleagues at Bangor, but it would be premature to attempt to summarize even the results already obtained. It is perhaps sufficient for the present purpose to say that, while the soils of Wales vary greatly and range from the blown sands in some coastal areas to heavy clays in a few of the valleys, or from deep peat to almost bare rock in the rough grazings, the majority of the soils under cultivation would be described by a farmer as of a loamy type, the areas of heavy clay or light sand being very limited. The Cambrian, Ordovician, and Silurian rocks, which form the main mountain masses and occupy the greater part of a geological map of Wales, give rise to perhaps the most characteristic sedentary soil—a loam containing a large proportion of unweathered fragments of shale.

There are also large areas of Old Red Sandstone in Brecon and Monmouth, but much of it is hilly country mainly devoted to sheep. Important outcrops of mountain limestone occur in both north and south Wales, and in the Vale of Glamorgan there is a considerable stretch of productive heavy soil derived from the Lower Lias. This, unlike most Welsh soils, is well supplied with lime. Glamorgan is in the main, however, dominated by the coal industry, which is the chief support of the large industrial population in this county. Coal mines are also to be found in the eastern districts of Denbighshire and Flintshire, but the industrial population there is small compared with that of South Wales. (See Soils.)

The majority of Welsh soils are of loamy texture, rather stony, rich in organic matter, and with a tendency to a deficiency in lime. Although the selection of arable crops is adapted to a rather low lime status in the soil, there is often a definite need for lime, particularly on light soils. Everywhere there is the tendency to depletion, which in all probability must eventually result in the need for a general resumption of the practice of liming.

Whilst the geology of Wales exerts an important influence on the character of the soils, and is reflected in the contrasts between soils derived from the older Palæozoic sediments, the Old Red Sandstone and the later formations, the variations among soils derived from the

AGRICULTURE, WALES (*Continued*)—

same or similar parent material are of equal, or, even, greater importance. (See Soils.)

From the practical standpoint, the conditions of water supply and of drainage in Wales are usually of greater importance than geological origin.

Drainage—Owing to the heavy rainfall, the question of drainage is naturally most important. While many stony hillsides are already sufficiently well drained, it must be admitted that there are very few farms which do not contain a proportion of wet or boggy land, and one of the great needs of the country is a renewal or extension of drainage systems of all kinds, ranging from the field drains to large arterial streams. The comparatively small area of real clay and the abundance of stones account largely for the fact that in many areas the proportion of old-fashioned stone drains to pipe drains is still high. It is difficult to prevent a stone drain from silting up, or to clean it when it has silted, so that there is more wet land in the country today than a generation ago. Mole draining has been tried and has produced good results in a few cases, but the presence of stones and the low proportion of clay will probably prevent any extensive application of this cheap method of draining. (See Draining.)

Markets—The industrial districts of South Wales provide an outlet for all kinds of farm produce, but the study of a railway map will show that few Welsh counties can take full advantage of these markets, which are more readily accessible from some adjoining English districts, and even by sea from Ireland. Visitors to the health resorts along the coast and in the mountains increase the local demand for a short period in summer, but the farmer of north and mid-Wales has to look for his main markets to the rather distant industrial districts of Lancashire and the Midlands. Therefore, in spite of the great improvement effected by the development of motor transport, most Welsh farmers still find themselves rather strictly limited in their system of farming by the difficulty and cost of marketing their produce. (See Marketing.)

Size of Farms—The average size of holding in Wales—45 acres—is smaller than the average English holding of 66 acres (if holdings less than five acres are excluded the respective areas are 53 and 83 acres), and on most farms in Wales there is some land which, though included as "grass," is little better than rough grazing. The difference in the proportion of large farms is still more striking. Only 5 per cent. are over 150 acres, compared with 13 per cent. in England.

The male workers "employed" on the farms average less than one per holding, and of the total number a large proportion are doubtless sons of the farmers. As may be expected, fields also are small, and this fact alone prevents the extensive use of the labour-saving machinery which is so necessary for arable cultivation. On the other hand, the small enclosures facilitate regulation of the grazing, and the stone walls or solid banks which often form the boundaries provide the shelter so necessary for young stock in wet, stormy weather.

AGRICULTURE, WALES

GENERAL CHARACTER OF WELSH FARMING—In a country so varied, it seems better to give a short sketch of two or three of the most important types of farming than to describe a purely hypothetical average farm.

(*a*) **Small Mixed Farm**—This is the most widely distributed, and probably the most characteristic type of farm. A typical example would include 40 or 50 acres of cultivable land of medium quality with some rough grazing. Many of these farms are in close proximity to unenclosed mountain land, from which they have obviously been reclaimed, and, in addition to the grazing on the farm proper, there are often rights to graze a certain number of stock on the mountain land. Rainfall in most cases would be 35 to 55 inches per annum, and the elevation might be anything from 50 to 800 ft. above sea level.

Rotation—The proportion of land under the plough at any one time is small, but the effect of the plough on the general economy of the farm is great. In the western districts, at least, there is not the sharp differentiation between arable and grass land which exists in most parts of England and in some of the eastern districts of Wales itself. The farmer can, and does, plough nearly all the fields in turn. Where the soil is dry or stony, and grazing by sheep, particularly in spring, is intense, the better pasture grasses fail to hold their own against the encroachment of bent, so that serious deterioration is apt to occur after four or five years. On the other hand, it is very easy both to break up and to lay down long leys. Usually, therefore, the fields are ploughed in turn and put through a short rotation preparatory to re-sowing. Oats are almost invariably taken as the first crop, roots usually follow, and oats, or sometimes barley, form the nurse crop for the grass seeds. A study of Table 2, p. 124, shows that this rotation is frequently modified. The area of corn is much more than double that of roots. A second corn crop may be taken after ploughing up the grass, and a certain amount of land is seeded down after two or three corn crops without having been under roots at all. In hilly districts or in distant fields, rape may take the place of roots, and to some extent upland fields are re-seeded without a rotation, rape being used as a nurse crop.

The cultivation during the rotation not only prepares the way for re-seeding, but also helps to provide winter food for the cattle. This is particularly important for the young stock, which, as will be seen later, are largely reared on this type of farm. Although the crops are grown mainly for home consumption and not for sale, the rapidly falling prices of arable crops have resulted in a tendency to lengthen the rotation, so as to reduce the proportion of corn and roots. It is fortunate that during the last ten years, when this tendency has been very pronounced, there have been great advances in the seeding of land to grass. In particular, the practice of sowing wild white clover has become fairly general, so that there has been a great improvement in the temporary leys and a distinct postponement of the stage of obvious deterioration. But for this, many of the pastures on this

AGRICULTURE, WALES (*Continued*)—

type of farm would have been very unsatisfactory by now. Here, the function of the plough is quite as much to maintain the production of the grass land as to secure the growth of arable crops. The young pastures are more productive than old pastures on the same land would be, and they are capable of rearing better stock, on which the Welsh farmer so greatly depends.

Cattle Rearing—It is on this type of farm that the majority of the store cattle, which are still one of the most important products of Welsh agriculture, are reared. In view of the small size of the farm and the large proportion of grassland, some form of dairying is practically essential to secure a sufficiently high production to support a family. In South Wales there is an important market for milk, and in most districts of Wales any local outlet for the sale of milk is fully exploited, but on the great majority of farms of this type the only practicable outlet for milk is the rearing of store cattle and the sale of butter. Calculations are often made to show the low returns received for milk used for butter making, but these usually ignore the fact that in a country like Wales the store cattle are nearly as important a source of revenue as the butter, and that the alternative is not milk selling or cheese making, but the rearing of calves on the cow or some other completely different system of farming. Many attempts have been made to establish creameries and butter factories, but without much success, in spite of the great improvement in the quality and marketing of the butter which could be secured. To some extent, the relative importance of calf rearing accounts for the difficulties experienced. Emphasis is placed on the advantages of having separated milk available for the calves in warm, fresh condition. It is interesting, perhaps, to note that the practice of churning whole milk still survives in many upland districts.

On this type of farm, with a certain proportion of cheap second-rate grazing, young cattle can be summered comparatively cheaply, and the arable crops provide suitable winter food for them as well as for the dairy cows. Bad hay harvests are frequently experienced, and in winters following such, young stock would fare badly if hay were the only home-grown feeding stuff. Dealers and graziers now complain that it is more difficult to obtain good bunches of store cattle than formerly. To a large extent this is due to the reduction in the arable area. The value of a store beast depends very much on the treatment it has received during its winter periods. The increase of dairying is, however, the main reason for the decline in the number and quality of stores. When milk can be sold few bullocks are reared, and in aiming at milk production there is a tendency to breed cattle which are not very desirable for beef production.

On this type of farm, the receipts from store cattle and butter, together with eggs, poultry, and pigs, are the main sources of income. If the farm adjoins a mountain grazing there will also be the sales of ewes and store lambs or of "couples" in spring. In other cases no flock is kept, but ewe lambs from the large mountain farms are taken in for the winter. On the other hand, outgoings, except for

AGRICULTURE, WALES (*Continued*)—

rent and the family's living expenses, are very small. Little or no hired labour is employed, and the expenditure on seeds, manures, and feeding stuffs is usually not great, though it might often with advantage be increased on the first two items with a view to reducing the third. The farm is, in fact, a good example of the family farm, now so often idealized, and there can be no doubt that the system possesses stability. A large proportion of the farms are in the hands of men whose families have held them for generations.

(*b*) **Larger Lowland Farms**—In the valleys and lowland districts there are many holdings of a larger size than the small farms already described. Some, owing to their situation or neglect of drains, contain a good deal of wet land, and these illustrate what has been said of the urgent need of greater attention to drainage. On the majority of such farms there is, however, a large proportion of good sound land, though usually not of first quality. Here and there are to be found farms which contain land capable of fattening cattle in summer without cake, but such land is exceptional.

On most of these larger lowland farms mixed farming was formerly the practice, and the sale of some portion of the arable crops used to contribute materially to the annual income. Some cattle were reared, but usually not sufficient for the total requirements, and a few stores were purchased both for winter and summer fattening. The extensive cattle yards which are now rarely filled indicate the extent to which winter feeding of cattle was formerly practised. A comparatively small flock of sheep was kept, and these were generally cross-bred ewes of a rather large size. Nowadays a completely different system prevails. Very little ploughing is done on farms of this class, and winter fattening is so little practised that a purely agricultural county like Anglesey has to import some of the beef required for its own consumption in late winter and spring.

Where circumstances favour the sale of milk, many of these farms are now devoted largely to dairying, but except on the purely dairy farms one of the chief sources of income is the sale of fat lambs. These are usually cross-bred lambs bred from Welsh mountain ewes, but in some cases ewes of a somewhat larger type, such as Kerry Hills, or cross-bred Kerry × Welsh, are preferred. No attempt is made to maintain a permanent flock, and the ewes are purchased in the autumn as drafts from the mountain flocks. They are mated with suitable rams, Southdown, Border Leicester, Suffolk, Western Horned (or Wiltshire), and Ryeland being perhaps the most popular. The ewes are kept for one or two years and then sold fat.

At the same time a tendency to attempt the summer fattening of cattle on a much larger scale has developed. Formerly, Wales was the happy hunting ground of the English dealer and grazier who wanted store cattle for fattening on the pastures of the Midlands. Nowadays, the export of store cattle is much less because fewer bullocks are reared and many are bought from the small rearing farms by the larger farmers in Wales. Unfortunately, very few have land of the

AGRICULTURE, WALES (*Continued*)—

quality required for real summer fattening, and although a great many cattle are taken to Lancashire and other markets which do not require a well-finished animal, the markets are often glutted in autumn with half-fat cattle which are really no better than good stores and ought to be retained for a further period of winter fattening. It is quite conceivable that this state of affairs will be one of the most important factors in ultimately securing an increase in the ploughed area. The dearness of store cattle in spring and the glutted markets in autumn seem likely to lead to more rearing and more winter finishing of fat cattle. Both these can be best done when arable crops are available.

Another factor tending to the same result is the difficulty of maintaining the productivity of the grass land under the present system of management. The stock of sheep carried is very heavy, and the grazing is intense during the critical months of April and May. On the lighter, drier soils, stocked mainly by sheep and grazed excessively bare in the late spring months, it is extremely difficult to prevent the encroachment of bent grass. In order to maintain a satisfactory type of herbage, recourse to the plough and to re-seeding sooner or later is necessary.

There is also another factor: it is common knowledge that land stocked heavily with sheep year after year tends to become "sheep sick," and that many lambs bred on such land do not thrive properly. Whether this is due to increasing infection of the land with parasites or to the growth of herbage deficient in mineral constituents, it is certain that the productivity can most certainly be restored by putting the land through a short rotation of arable crops.

(*c*) **Mountain Sheep Farms**—The sheep population of Wales is greater in proportion to the area of crops and grass than that of any part of England, except Northumberland and Westmorland, and even if rough grazings be included the population is roughly one sheep per acre as compared with one for two acres for England as a whole. This is, of course, largely due to the high proportion of mountain land and the fact that it is now customary to use the mountain land almost exclusively for sheep. The existence of the mountain flocks has many influences on the lowland. They provide the source from which the lowland flocks are periodically renewed, and they also require the use of the lowland for wintering purpose. The ewe lambs and a proportion of the adult ewes cannot be kept on the high mountains in winter, so that many small farmers in lowland districts keep no sheep of their own, but take in sheep from the mountain farms at an agreed price per head for the winter. The presence of these sheep in early spring months is one of the factors to be reckoned with in considering the management of grass land on such lowland farms.

The mountain flocks are extremely varied in size. Many small holders and cottagers, as well as farmers, keep a few sheep, which graze on the common or unenclosed mountain for the greater part of the year, but the mountain farms proper are usually fairly large, grazing at least 200 or 300 ewes. The land may be all at a consider-

AGRICULTURE, WALES (*Continued*)—

able elevation, in which case some of the ewes as well as the ewe lambs will be sent to lowland farms for the winter, or it may contain a certain proportion of lowland or grazing of intermediate type, which can be used for wintering. By far the most important breed of sheep is the native Welsh Mountain, which, as regards numbers, is only surpassed in Great Britain by the Scotch Blackface. In mid-Wales larger breeds, of which the most important are the Kerry Hill and Radnor, are kept on hill land of less elevation and better quality than ordinary "Mountain." At various times, Cheviots and Blackfaces have been tried in practically every part of Wales, but the former have only established a permanent footing on the Old Red Sandstone Hills of Brecon, the latter on the heather moors of East Denbighshire and Flintshire. The Welsh Mountain is a small, hardy type of sheep, with short, fine wool, and characterized by remarkable activity, which is necessary for securing a living on the stony hillsides which form its native habitat. In addition to the small joints and high quality mutton, which one naturally expects in such a sheep, the Welsh ewe has remarkably fine milking qualities, and is thus excellently suited for the rearing of fat lambs. The recognition of this fact, together with the modern demand for small joints, has led to a great demand for the draft ewes in recent years, and Mountain ewes have now everywhere largely taken the place of the larger breeds and crosses which were formerly kept in lowland districts.

On most mountain farms a few cattle are kept throughout the year, and some hay must be made for their winter keep. Incidentally, it is to be deplored that more cattle are not maintained on many of these farms. Formerly, they carried considerable numbers during the summer with great benefit to the grazing, and the cattle gave a little direct financial return. Young store cattle were bought in spring and sold at special sales in autumn. Now, owing to the reduction of arable land in the lowlands, the cost of stores in spring is often excessive compared with the price likely to be realized for them in autumn.

In the case of the mountain farms, although the area may be large, a great many are essentially family farms, and, whatever the income may be, the outgoings are very small. In recent years the prices of store sheep have been well maintained and the net returns from this type of farm have compared favourably with those of farms in localities more favoured by nature.

CHANGES DURING THE PAST GENERATION—The table on p. 124, extracted from the official agricultural statistics, indicates some of the most important changes which must first be considered.

Reduction in Tilled Area—The most important and most obvious change is the great reduction in the area of tilled land, which has shrunk in the last forty years by more than 45 per cent. The same fact may be put in another way: In 1888 the proportion of tilled land was over 20 per cent. of the total area of crops and grass; it is now less than 13 per cent. The proportionate reduction is heaviest in the case

AGRICULTURE, WALES (*Continued*)—

of wheat, about 75 per cent., and barley, about 60 per cent.; the combined area of the two is now only a little more than one-third of the area under oats. The reduction in the area of wheat is largely due to the laying down of heavy land to grass, but it also illustrates differences in mode of life. It was formerly the practice on farms throughout Wales to grow at least enough wheat to supply the farm house with its own bread throughout the year. Now, even where home baking is still practised, the white "strong" flour produced largely from overseas wheat in a modern mill supplants the rather dark, "weak" product of the comparatively sunless climate and the old-fashioned local mill. (See Wheat.)

TABLE 2.

WALES, INCLUDING MONMOUTH.

	1888.	1908.	1928.
		Thousand Acres.	
Total cereal crops	473·6	339·4	253·1
Beans, peas, and vetches	10·5	2·9	1·7
Roots, potatoes, etc.	151·4	114·0	91·4
Total tilled land	635·5	456·3	346·2
		Thousands.	
Total cattle	711	782	818
Cows and heifers in milk or in calf ..	293	304	333
Other cattle two years and above ..	130	95	83
Total sheep	2,917	3,972	4,000
Sheep under one year	966	1,463	1,547

Similarly, the reduction in the area of barley is due partly to the disappearance of the local malt kiln and brewery, but to some extent it is doubtless connected with the discontinuance of the practice of liming land. In North Wales, at least, it is noticeable that the liming of arable land is now practically restricted to those farms which grow barley, and *vice versa*. (See Lime and Liming.)

Changes in Livestock. (1) *Sheep*—The most striking change is the great increase in the number of sheep, from less than 3 million in 1888 to more than 4 million in 1928. The largest proportionate increases have occurred in those counties which are largely or mainly lowland, for instance, Anglesey, Denbigh, Flint and Pembroke. There have also been increases in the counties where mountain land predominates, but, even there, it may be surmised that there has been less increase on the mountains than in the valleys. Reference has already been made to the change in type of the lowland stocks.

AGRICULTURE, WALES (*Continued*)—

Mountain or hill sheep have everywhere taken the place of the larger breeds.

Growth of Fat Lamb Industry—Agricultural returns are collected on June 4, so that the number of "sheep under one year" gives only an approximate measure of the number of lambs reared, as a large number of lambs are now sold for slaughter before that date. As this is a comparatively recent development it is certain that the figures quoted underestimate the change. The growth of the fat lamb industry, which is now one of the main sources of income on most lowland farms (see page 121), is one of the most important changes which has taken place, and accounts for the very large increase in the number of sheep in four or five of the lowland counties already mentioned. Even in 1930 the prices of fat sheep have been 60 per cent. more than those ruling in the corresponding months of 1911-1913, and this, combined with the lower labour costs, has enabled the farmer who has developed this type of farming to hold his own comparatively well. Much as the reduction in employment and the lower productivity of the farm may be deplored, there can be no doubt that but for the development of the fat lamb industry many of the lowland farmers of Wales would be in as straitened circumstances as many of the arable farmers of the east of England.

Replacement of Wethers on Mountain Grazing—A change, too, has taken place in the sheep of the mountain land. It used to be the general practice to keep the wethers on the mountain until they were at least three years old. Now, the common practice is to sell the wether lambs as stores, and they are usually fattened off by the lowland farmer before they are a year old. There is little demand now for old wether mutton, largely because of the fact that unless well hung before cooking it is rather tough, and the modern demand is for young, tender meat, which can be cooked at once. The following table, taken from the *Journal of the Farmers' Club* for December, 1929, shows the extent of the change. The counties named have a large proportion of mountain land:

TABLE 3.

COMPOSITION OF SHEEP FLOCKS OF BRECON, CAERNARVON, CARDIGAN, MERIONETH, MONTGOMERY, AND RADNOR.

	1907–08.		1927–28.	
	Thousands.	*Per Cent. of Total.*	*Thousands.*	*Per Cent. of Total.*
Ewes for breeding ..	889	38	1,024	43
Lambs	772	33	881	37
"Other sheep"	652	28	459	19
Total sheep	2,313	—	2,364	—

AGRICULTURE, WALES (*Continued*)—

Incidentally, the reduction in the number of wethers kept on the mountain has enabled the stock of ewes to be increased, and consequently the crop of lambs is also greater.

The great reduction in the number of wethers has, however, had certain less desirable results. Formerly the wethers, after they were a year old, were left on the mountain winter and summer alike, and during the hard months of winter they did much to clear off any rough herbage which had been ungrazed during the summer. They thus tended to keep the whole area fairly uniformly grazed. In-lamb ewes must have better food during the winter if they are to lamb in reasonably good condition, with the result that the high mountain land is not grazed so effectively as before, and deterioration of the herbage has undoubtedly resulted. This effect is accentuated by the great reduction in the number of mountain ponies kept on high mountain land. With the introduction of mechanical haulage in coal pits there is now little demand for ponies.

(2) *Cattle*—The increase in the number of cattle (about 14 per cent.) has not been nearly so great as the increase of sheep, and it must be remembered that the official returns are collected on June 4. It is not unlikely that if figures were available a similar comparison based on the *winter* stocks of cattle would show either no increase at all, or even some reduction.

In view of the greatly increased importance of dairying, it is rather surprising to find that the number of cows in calf or in milk has not increased by more than 40,000; no more in proportion than the increase in the total cattle. In the last forty years the population of Wales has increased by nearly 70 per cent. as against an increase in cows of 14 per cent., so that it is obvious that most of the increased demands of the liquid milk market are being met partly by increased production per cow and partly by a diversion of milk from butter making and cheese making. In the absence of official figures, it is impossible to estimate what increase has taken place in the average production of the dairy cows of the country. The work of the Milk Recording Societies and the improved methods of feeding and management which have resulted from the activities of the County Educational Staffs have undoubtedly raised the level of production, particularly in the herds from which milk is sold as such. Probably, however, much the greater part of the increase in the supply of milk is due to the establishment of dairy herds for the sale of milk on farms where butter making and the rearing of cattle were formerly the chief business.

Changes in Breeds—Welsh Black cattle are regarded as the native breed of Wales, though it must be admitted that for many years Herefords and Shorthorns have outnumbered them in the Principality as a whole. Some idea of the relative numbers of the respective breeds may be obtained from the number of bulls stationed in Wales under the scheme of the Ministry of Agriculture for the Improvement of Livestock. The latest available figures are as follows:

AGRICULTURE, WALES (*Continued*)—

Welsh Black, 74. Of these 65 were stationed in Anglesey, Caernarvonshire, and Merionethshire.

Shorthorns, 188. Of these 149 were stationed in Cardiganshire, Carmarthenshire, Denbighshire, Flintshire, and Pembroke.

Hereford, 108. Of these 74 were stationed in Brecon, Montgomery, and Radnor.

A few Welsh bulls (nine in all) were also stationed in Cardigan, Carmarthen, and Pembroke, but the figures indicate clearly enough that Welsh cattle, which, not so many years ago, were the chief breed in south-west as well as north-west Wales, have lost ground in the south. Probably Shorthorns have taken the place of most of the Welsh Blacks which have disappeared, though, unfortunately, in many cases there has not been a simple substitution of one breed for another, but a great amount of indiscriminate crossing, which has resulted in serious deterioration of the cattle in the areas concerned. The replacement of Welsh Black cattle by Shorthorns is mainly due to the increase in dairying for the sale of milk and the prevalent idea that the Shorthorns are better milkers than the Welsh Blacks. E. J. Roberts has shown (*J. Agric. Sci.*, vol. xvi., part 3) that this is perhaps a mistaken view, probably based on the difference which exists in the form of the lactation curve. Even now, too many farmers judge a cow by the maximum amount of milk yielded in a day. Shorthorns give a higher daily yield when in full milk, but they dry off more quickly, and, actually, the total yield for the full lactation period may be no more than that of Welsh cows.

Reduction in Number of Old Bullocks—Table 2 shows that while the cattle population as a whole has increased by 14 per cent., "other cattle over two years of age" have been reduced during the past forty years by 35 per cent. This is due largely to the modern demand for young, tender beef, and the difference would doubtless be much more striking if the numbers could be analysed, separating out two-year-old and three-year-old bullocks. The change has doubtless contributed something to the reduction in the numbers of Welsh cattle, which are slower in maturing than Herefords or Shorthorns, and, though capable of being fattened at an early age, require for that purpose much better food conditions than those with which they are usually associated.

The change has also not been without effect on the rough grazings to which so many references have been made. When the bullocks were not to be sold as stores until two, or even three, years of age, they could be grazed for one or two summers on rough uplands. Now, even a two-year-old store is almost too old for modern requirements, and if the younger cattle are to be pushed on for sale at an earlier age they must have something better than rough hill pasture.

(3) *Horses and Pigs*—In view of the great reduction in the area of tilled land, and also the development of motor transport, it seems strange that the number of horses used for agriculture is actually somewhat greater now than forty years ago, though, possibly, a slight

AGRICULTURE, WALES (*Continued*)—

modification in the form of the returns may offer a partial explanation. The total number of horses, including young horses, is rather less than formerly.

The pig population has remained practically the same, though subject to the rather great fluctuations from year to year common to this form of livestock. On many farms the reduction in arable land and the change from cheese making or butter making to milk selling has resulted in a diminution of the herd, but this has apparently been balanced by the cases in which farmers have taken advantage of improved facilities for securing imported meals and feeding stuffs.

(4) *Poultry*, unfortunately, cannot be discussed in the same way as other stock, because official statistics are not available for more than a few years, but although Wales is backward in poultry keeping compared with many districts of England, there has been undoubtedly a great increase in the number of poultry, and at the same time, owing to improved methods of management and breeding, a great increase in the production of eggs per bird. Attempts at securing improvement in the marketing of eggs have met with more success than in the case of dairy produce, but seasonal fluctuations in supplies make the administration of Marketing Societies very difficult.

Schemes for the Improvement of Livestock—The growing importance of livestock in the agricultural economy of the country has naturally accentuated the inherited enthusiasm and capacity of the Welsh farmer for stock management. Even before the establishment of the official schemes, Livestock Improvement Societies of many kinds existed in Wales, but, without disparaging their work, it may be said that really systematic and persistent effort began in 1914, when the Ministry of Agriculture introduced its scheme. The following table shows how the scheme has grown.

	1914–15.	1929–30.
Bull Grants	167	370
Boar Grants	32	205
Heavy Horse Grants	21	29
Ram Grants	—	25
Milk Recording Society Grants	—	7

To those familiar with the work of such schemes, the figures will convey a good idea of the direct effect, but it may be added that the indirect effects are at least as important. The introduction of a superior sire into a rather backward district introduces a certain element of competition and results in a higher standard in the sires kept on other farms.

Agricultural Education and Research—The real interest of Welsh people in all forms of education has been shown not least in the development of schemes of agricultural education and research. In this work the University of Wales, through its constituent colleges, has taken a leading part. The Department at Bangor was established as such in 1888, and that at Aberystwyth in 1891. Cardiff College has not established a full Agricultural Department, but for some years

AGRICULTURE, WALES (*Continued*)—

it has had a staff of advisers in various subjects. From the start, the two Colleges made it their business not only to provide in-college courses for students, but also to institute schemes of agricultural education in the counties associated with them. From very small beginnings these have developed, until now each county has its own organizer, and, usually, instructors in special subjects. Four counties have established farm institutes of the residential type, and in other counties there are centres in which special instruction is given. With the devolution of ordinary county work which has taken place, the colleges have naturally concentrated on the development of higher work. Not only have there been established advanced courses providing for the needs of prospective specialists in various subjects, but there has been great development of research. Perhaps the best-known example of this is the Welsh Plant Breeding Station under the directorship of Professor Stapledon. The researches of Professor Robinson in soil chemistry and of Professor Ashby in agricultural economics are also well-known examples of the contribution which Wales is now making to the general stock of agricultural knowledge.

The advisory staffs at all the colleges are also engaged in research, and, while they concentrate more on problems of special local importance, their work has in many cases proved of very wide application.

The total expenditure on agricultural education in Wales is now in the neighbourhood of £80,000 per annum, a considerable sum for a country most of which has a very low rateable value. Such an expenditure would be altogether impossible were not the larger part provided by Government grants. In passing it may be mentioned that the Ministry of Agriculture and Fisheries has established a Welsh office at Aberystwyth, and this office has charge of the local administration of much of the Ministry's work, including County Schemes of Agricultural Education.

It is never easy to produce definite evidence of the results of educational work, though it is not difficult to point to individual cases where the results of agricultural research conducted in Wales have been of enormous direct value. Perhaps the most striking single case is Montgomerie's discovery of the value of carbon tetrachloride in the treatment of Liver Rot in sheep, which undoubtedly saves thousands of sheep annually in the wetter areas of Wales alone, to say nothing of its value in other countries. The development of improved strains of herbage plants and the devising of better methods of pasture management by Stapledon and his colleagues are other instances of work of great direct practical value. But, important though such cases are, it is probable that if it were only possible to assess the true value of the general educational work, the latter would prove to be of even greater value. Research, however striking its results may be, is of little immediate use unless there is a sufficient body of farmers with the necessary knowledge and enterprise to take advantage of it and to apply it in such a way as to suit local conditions.

The changes already described as having taken place in the farming of Wales during the last generation amount to little less than a revolu-

AGRICULTURE, WALES (*Continued*)—

tion. Although from many points of view they may at the moment appear retrograde, when the time comes to view them in their proper perspective it will almost certainly be seen that they represent a stage in the general progress of the country. When the fundamental nature of the changes is considered, and it is realized that the agriculturists of Wales have so rapidly adapted their various systems of farming to meet changed economic conditions, it will probably be conceded that a substantial tribute must be paid to the schemes of agricultural education.

In matters of detail the influence is obvious. There is no comparison, for instance, between the knowledge and practice of the present generation of farmers and of the past in such matters as the use of artificial manures, feeding stuffs, and the selection of seeds of all kinds for both arable and grass land. Sufficient reference has perhaps been made already to the improvement in the temporary leys, on which the farming of Wales so much depends.

Generally speaking, Welsh agriculture, though suffering in some respects from the present depression, is holding its own fairly well, and, though it is easy to say that this is largely due to the relatively high values of sheep and cattle, it is obvious that the Welsh farmer has shown marked capacity for modifying his systems to take full advantage of favourable circumstances. As against his advantages, it must be remembered that he suffers from disadvantages, too. In particular, many of the holdings are undoubtedly too small to form an economic unit, and in nearly all cases the fields and farms are too small to allow of the general use of labour-saving machinery, whilst the distance from suitable markets prevents any great development of "intensive culture" in most Welsh counties. R. G. W.

AGRICULTURE, WEST INDIES—The territories which include British Guiana and British Honduras, on the mainland, and the West Indian islands in British occupation, are unique in more than one respect. Historically they were the first tropical areas to be developed, and derived their importance as the first source of supplies of tropical produce, particularly sugar, for the English market. At the present time, of the islands, Trinidad alone finds in oil and asphalt a source of wealth which is not agricultural; while, as a whole, they offer a unique spectacle both in the variety of agricultural production and in the systems on which that production is conducted. Originally based on a plantation system conducted with slave labour, agriculture is still largely conducted on that system. With the liberation of the slaves, the plantations drew on East Indian labour, particularly in British Guiana and Trinidad, under an indenture system, and, intermingled with the plantations, has arisen throughout a system of peasant cultivation conducted by both the descendants of the emancipated slaves and by East Indians whose terms of indenture have expired. The soils are equally varied. Those of British Guiana and Trinidad, which is continental in origin, are very variable, but are, generally speaking, heavy clays which tend to be acid in reaction.

AGRICULTURE, WEST INDIES (*Continued*)—

Many of the West Indian islands are still actively volcanic, with a rich and fertile soil. Others, again, like Barbados, are entirely, or almost entirely, of coral formation. All lie within the tropics, and have an equable climate with a well-distributed and adequate rainfall. Throughout, drought is of rare occurrence. The most serious adverse climatic feature is wind. From July to October hurricanes sweep across the islands with the exception of Trinidad and Grenada, and cause wide damage to the crops of any island that happens to lie in their direct path. On the human side conditions are equally divergent. British Guiana and Honduras have a sparse population which prevents development of the hinterland, while, at the other extreme, Barbados has a population approximating to 1,000 per square mile. This question of population, in view of the limited area of many of the islands, and their dependence on the external world for all but the elementary requirements of life, offers a problem of considerable economic interest, for the limits to expansion unrelieved by emigration are soon reached. Any increase of wealth due to greater agricultural productivity is soon compensated by an increase of population, leaving the *per capita* wealth but little changed. There is, thus, built up a position of unstable equilibrium very easily upset by adverse conditions in the export market.

British Guiana—Plantation cultivation is practically limited to sugar, which is grown on the lands reclaimed from the sea. (See Sugar-Cane.) Cacao is grown to a small extent, but has received a set-back through Witch-broom disease. (See Cacao.) In recent years cultivation of rice has expanded and offers a promising field, especially as a peasant crop for the considerable settled East Indian population. The hinterland is practically undeveloped agriculturally through lack of population. The agriculture of the territory has been reviewed by Sampson (*Empire Marketing Board Rept.*, iv., 1927), while for the potentialities of the country for rice the report by Douglas may be consulted (*Empire Marketing Board Rept.*, xxxii., 1930).

Trinidad and Tobago—These islands supply a varied range of agricultural products. On the lowlands of the west and the undulating country of the Naparima district sugar predominates, and there are a number of up-to-date and efficient central factories. Cane is grown directly on the plantations or on the farming system, the peasant receiving "cane seed" and an advance from the factory to which he undertakes to supply his cane. The crop is subject to cycles of extensive damage from "Frog-hopper." (See Sugar-Cane.) Cacao is produced particularly in the north and central ranges, and in Tobago, either as a plantation or peasant crop. The recent appearance of the Witch-broom disease in a few localities is a present cause for anxiety. Coconuts are extensively cultivated, mainly in the east and south-west. Para rubber grows well, and a few estates tap on a commercial basis. Fruit production for export has been restricted by lack of facilities for marketing, but, with the institution of a direct line to Canada, the production of citrus fruits is likely to develop, with possibilities of

AGRICULTURE, WEST INDIES (*Continued*)—
such fruits as the Avocado pear and mango as subsidiary products. Peasant cultivation is concerned here, as in the other islands, with maize, sweet potato, yams, tannia, and eddoes. Rice is also grown to a minor extent by the East Indian population. The agriculture of the territory has been reviewed by Sampson (*Empire Marketing Board Rept.*, iii., 1927).

Grenada—The main crop of this volcanic and mountainous island is cacao. Sugar is also grown to a minor extent, while there is also an export of nutmegs and mace. The agriculture of the Windward and Leeward Islands has been reviewed by Sampson (*Empire Marketing Board Rept.*, v., 1927).

St. Vincent—While this island, which displayed disastrous volcanic activity as late as 1902, produces sugar, cacao and coconuts, its main crops are arrowroot (*Maranta arundinacea* L.) and cotton. The cotton is "Sea Island."

St. Lucia—The island is, again, volcanic and mountainous. In addition to the crops already indicated in the islands previously noted, it produces limes, and there is a considerable export in lime juice. The cultivation of limes has, however, received a check through the attack of "Wither-tip" (*Glœosporium limetticolum* Clausen) in epidemic form. An account of the Wither-tip and certain aspects of its control is given by Williams (*Trop. Agric.*, vi., 7, 1929).
A recent attempt to grow bananas for export failed. (See Banana.)

Barbados—Barbados is at once the earliest of the West Indian Islands to be developed, and the most densely populated. It is almost entirely a coral formation, and lacks the high altitudes of the volcanic islands. The high rainfalls characteristic of those islands do not occur, and the fall is relatively light. The coral rock is, however, porous and retentive, and, generally speaking, the moisture is adequate for sugar, which is the dominant crop. To such an extent is this the case that the prosperity of the island is bound up with sugar. The crop is grown on relatively small plantations, and, in the absence of modern central factories, a considerable portion of the output consists of fancy molasses. Barbados is noteworthy for the work of Bovell and Harrison on seedling canes. (See Sugar-Cane.) Sea Island cotton is also grown, and the main pest is the bollworm, which, in the absence of any dead season, is only kept in check, as in the other islands in which cotton is grown, by strictly enforced regulations for the fumigation of seed, and for the control of the planting season, and by supervision of the import of seed.

Dominica—This southernmost of the Leeward Islands is volcanic. The major crop is limes, and the products thereof constitute the dominant export.

Mont Serrat—Though the original producer of lime products, this volcanic island has been outstripped by Dominica, the industry having received a severe check in 1899 from hurricane. Its main

AGRICULTURE, WEST INDIES (*Continued*)—

crop is Sea Island cotton, while it also produces papain from the pawpaw (*Carica papaya* L.).

With the establishment of a direct sea-borne service with Canada an export trade in tomatoes is rapidly developing in this and the neighbouring islands.

Antigua, St. Kitts, and Nevis—Sugar is the predominant crop of these islands, which are partly volcanic and partly of coral formation. The crop is handled by central factories. Cotton is also grown to a limited extent.

Jamaica—This, the largest of the West Indian islands in British possession, is exceedingly mountainous, the highest peak being over 7,000 ft. Jamaica, consequently, offers a wide range of conditions, and agriculture is correspondingly varied. Sugar, coffee, cacao, coconuts, tobacco, bananas, and citrus fruits are all grown, while there is a well-developed stock and dairying industry. Sugar production is developed around central factories, while the banana industry is now highly organized under a producers' organization, and fruit is shipped in quantity to America, Canada, and England. The variety grown is the Gros Michel, and the most serious enemy is the Panama disease (see Banana), though hurricanes occasionally cause severe damage to the plantations.

British Honduras—This considerable tract on the east coast of Central America can hardly be said to be as yet developed agriculturally. Its main products are sylvicultural, but bananas and coconuts are produced on a comparatively small scale. The potentialities of British Honduras for agriculture have been dealt with by Sampson (*Empire Marketing Board Report*, xvi., 1929). H. M. L.

AIR—The composition of the air is somewhat variable, though by no means to such an extent as might be imagined. It consists almost entirely of the two gases, oxygen and nitrogen, about 21 per cent. of the former to 77 or 78 per cent. of the latter; the remaining 1 to 2 per cent. being accounted for by water vapour, carbon dioxide, and the rare gases helium, argon, neon, krypton, and xenon. The above percentages vary somewhat with latitude, since round the equator there is naturally a much greater proportion of water vapour present owing to the enormous evaporation, while about the poles most of this is frozen out of the air.

The oxygen of the air destroyed by animals is re-formed by green plants in daylight, when the chloroplasts contained in them are able to use the carbon of the carbon dioxide for building up the organic matter of their own tissues and liberating much oxygen in the process. It is indeed a fact, but, as Professor J. A. Thompson points out in the *J. Min. Agric.*, December, 1929, not by any means a well-recognized one, that the plants of the world in older times have actually manufactured the oxygen for us; there can have been but little in the original gaseous envelope of the earth.

Another constituent not usually noticed from a chemical point of

AIR (*Continued*)—

view has a considerable influence in agriculture—namely, the solid matter in the air. Space does not admit of even an approximate enumeration of the solids which *may* be found, for the agriculturist they may be divided into two classes: (i.) soluble matter, (ii.) insoluble matter. The former includes sea salt; in coastal regions this is often present in sufficient quantity to seriously impede growth, and the same is true to a still greater extent of the chemicals in the air surrounding towns. The insoluble matter may be in the form of dust and sand, as on the margins of desert, or it may be soot and other constituents of smoke which in urban districts operates, according to the experiments of Crowther and Ruston (*J. Agric. Sci.*, vi., 387-405, 1914), both in reducing the available sunlight and in blocking the stomata in the leaves. The acids in the rain of urban districts also have, according to these investigators, an effect in increasing the fibre and decreasing the protein in a crop of timothy hay, and this, if found general in forage crops, would be serious. (See Meteorology.)

ALCOHOL—Chemically, any compound which can be represented by formula $R.CH_2OH$; $\begin{matrix}R\\R\end{matrix}\!\!>CH(OH)$; or $\begin{matrix}R\\R\\R\end{matrix}\!\!>C(OH)$, though the last are often called carbinols. The name is, however, when used alone, taken to mean a compound—ethyl alcohol (C_2H_5OH), which is one of the principal products of the fermentation of sugar by the enzyme of yeast, when the following reaction ensues:

$$C_6H_{12}O_6 = 2CO_2 + 2C_2H_5OH;$$

where higher sugars are used, they are first broken down to hexoses by other ferments. (See Carbohydrates.) Commercially, the production of alcohol is of great importance, involving as it does the brewing, distilling, and wine-making trades, together with a very large number of other staple industries in a minor degree, such as pharmacy, power fuel, paint and varnish trades, artificial leather and silk making, the manufacture of explosives, etc.

The sale of alcohol is regulated in almost all countries, and in most is made to yield a handsome return to the national exchequer.

Methylated spirit was originally alcohol to which a small percentage of wood naphtha consisting largely of methyl alcohol (CH_3OH) had been added to render it non-potable. In December, 1925, however, the regulations were tightened up considerably, and since 1928 mineralized methylated spirit has consisted of 90 parts of alcohol by volume, $9\frac{1}{2}$ parts wood naphtha, $\frac{1}{2}$ part crude pyridine, a coal tar product of most offensive odour, with 3 pints of mineral naphtha and $\frac{1}{40}$ oz. of the dyestuff methyl violet, added to each 100 gallons.

The production of power methylated spirit has progressed considerably in recent years, more especially since it has been proved possible to produce it under commercial conditions from non-food plant tissues, chiefly from hemicelluloses, etc. In Germany and the

ALCOHOL (*Continued*)—

Scandinavian countries considerable quantities of power methylated spirit is used. By a regulation of 1921 this now consists in Great Britain of 92 parts alcohol, 5 parts benzole, $\frac{1}{2}$ part pyridine, $2\frac{1}{2}$ parts wood naphtha, and $\frac{1}{40}$ oz. spirit red III per 100 gallons, and must be mixed with 25 per cent. petrol or other fuel before use, which makes it much easier to start up from cold.

Pure duty-free spirits may be obtained since May, 1911, by Universities, Colleges, etc., for use in laboratories.

"Proof spirit" was at one time alcohol of such strength that when it was used to wet gunpowder and then ignited, the gunpowder was just ignited as the flame died out. Now it may be taken to be alcohol of 49·28 per cent. strength.

The prevalent idea that alcohol is a heart stimulant is incorrect, though it may cause stimulation indirectly; cases of fainting occur in which brandy is useless, while sal volatile and smelling salts will bring the patient round easily.

ALFALFA—See Lucerne.

ALFALFA MEAL—For value when fed to poultry see Poultry, Nutrition.

ALKALI—Oxides, hydroxides, and carbonates of lithium, sodium, potassium, rubidium, and cæsium, also of magnesium, calcium, strontium, and barium. The oxides and hydroxides of the metals in the first group and the oxides of those in the second are known as *caustic alkalies*. Alkalies have the property of neutralizing acids, forming salts. The term alkali is often, by common usage, extended to include salts of the metals in the first group with weak acids, *e.g.*, borax is a borate of sodium. Their use in agriculture is limited, but the oxide and hydroxide of calcium, quicklime and slaked lime respectively, are important. (See Lime and Liming; and Acid.)

ALLOTMENTS, STATUTORY ENACTMENTS RELATIVE TO — The ancient Common Law of the Kingdom recognized customs permitting lords of Manors to enclose waste land provided sufficient of the Common was left for the Commoners, and this was affirmed in the thirteenth century by the Statute of Merton, 1235, and the Statute of Westminster the Second, 1285; the onus, however, of proving that a sufficiency was left lay with the lord. In general, however, the inclosure of land forming part of a Common required the authority of an Act of Parliament. Inclosures became frequent at the end of the sixteenth, and were continued on a large scale until the nineteenth, century. During this period the inclosure of lands was generally considered a benefit to the nation as a whole, and no doubt more land would have been inclosed had not private Acts of Parliament authorizing such inclosure involved great expense. Many of these Acts deprived Commoners of their rights of Common without adequate compensation, as owing to their poverty they were not in a position to protect their interests. In course of time the need for the protection of the community became apparent, and Inclosure Acts made

ALLOTMENTS (*Continued*)—

provision for the setting aside of land for allotments to take the place of such rights of common of which the community were deprived. These allotments were vested in private persons as trustees, or in overseers and churchwardens.

The necessity for obtaining private Acts of Parliament to authorize inclosure of land was, in many cases, abolished by a Statute of 1836, which permitted the inclosing of waste and common lands upon the consent of two-thirds in number and value of the persons having rights of common or other rights therein. Such persons consenting had to appoint Commissioners for dividing, allotting, and inclosing the land, unless seven-eighths in number and value of the persons interested had consented. It was the duty of the Commissioners to apportion, divide, and allot such land amongst the various persons in accordance with their interests therein, and the Act made provision for the publication of a description of land proposed to be awarded, and as to an appeal from decisions of the Commissioners appointed.

Inclosure Act, 1845—Inclosure Commissioners were introduced by the Inclosure Act, 1845. These Commissioners were empowered to make provisional orders authorizing inclosures of land, and an annual report of their proceedings was directed to be laid before both houses of Parliament. In provisional orders authorizing the inclosure of land subject to rights of common, the Commissioners might require and specify, as one of the terms and conditions of such inclosure, the appropriation of such an allotment for the labouring classes as they should think necessary, and if in the provisional order for such inclosure the Commissioners did not require the appropriation of land for the labouring poor, they had to state in their annual report the grounds on which they had abstained from requiring such appropriation. Allotments for the labouring poor established under the Act became subject to the management of allotment wardens. In very few instances were private Acts of Parliament authorizing inclosures applied for after the passing of this Act, with the result that allotments provided on the inclosure of lands since that date became established on a uniform basis.

Poor Relief Act, 1819—Experience proved that in rural districts, where allotments were provided for the labouring classes, the poor rates became considerably reduced. This fact, strengthened by a report of a committee of the House of Commons recommending the extension of allotments, led to the formation of societies for the provision of allotments and to the passing of the Poor Relief Act, 1819. This Act empowered churchwardens and overseers of any parish, with the consent of the inhabitants thereof in vestry assembled, to take into their hands land belonging to the parish, and to purchase or hire land within or near the parish, not exceeding 20 acres in the whole, for the purpose of giving employment to the poor, and also to let portions of such land for cultivation by poor and industrious inhabitants of the parish. Two Acts of 1831 extended the right of churchwardens and overseers to acquire land for these purposes to the extent

ALLOTMENTS (*Continued*)—

of 50 acres, and, subject to certain conditions, to inclose waste lands to such extent.

Allotments Act, 1832—Allotments provided by the local Inclosure Acts were in most cases set out for the benefit of the poor, chiefly with a view to fuel, *i.e.*, the taking of peat or turf. In several cases these allotments became comparatively useless and unproductive. The Allotments Act, 1832, authorized the trustees of such allotments, together with the churchwardens and overseers in vestry assembled, to let the allotments to industrious cottagers within or near the bounds of their parish, in portions of not less than ¼ acre and not more than 1 acre, on a yearly Michaelmas tenancy at a rack rental, and to apply the rents received in the purchase of fuel to be distributed among the poor parishioners resident in or near the parish. Power was also given to vestries to make orders letting allotments found to lie at an inconvenient distance from the residences of the cottagers and to hire, in lieu thereof, land of equal value more favourably situated. In 1835 the powers and duties of churchwardens and overseers under the Acts were taken over either by overseers of the poor or Guardians of Poor Law Unions.

Poor Allotments Management Act, 1873—The Poor Allotments Management Act, 1873, directed that in the cases of allotments provided:

(*a*) by any local Act of Inclosure prior to the Inclosure Act, 1845, where the number of the allotment trustees for the time being exceeded twenty; and

(*b*) by the vestry of a parish under the Poor Laws before mentioned, where the number of persons for the time being entitled to attend such vestry exceeded twenty,

such trustees and vestry respectively should annually appoint a Committee of not more than twelve nor less than six members of their body, which committee, during the year of their continuance in office, should exercise the powers of the authority appointing it. If any authority required to appoint such committee failed to do so within the time specified by the Act, the Inclosure Commissioners might make such appointment on the application of any person interested. The Act also directed that rents of allotments provided under the Poor Laws should thenceforth, after deduction of all proper charges, be applied in aid of the poor rates.

Allotments Act, 1887—The provision of allotments was greatly facilitated by the Allotments Act, 1887, as a result of which statistics show that between 1886 and 1890 the number of allotment holders in England and Wales increased by approximately 25 per cent. This Act introduced the right of local authorities to acquire land for allotments by providing that if, in the opinion of any sanitary authority of an urban or rural district, there was a demand for allotments for the labouring poor within their area, and that allotments could not be obtained by such persons at a reasonable rent and upon reasonable

ALLOTMENTS (*Continued*)—

terms, such sanitary authority should purchase or hire suitable land that might be available to meet such demand provided that they were of opinion that the rents to be obtained would recoup their expenses except such expenses as would be incurred in making roads for the public. In cases where sanitary authorities were unable to acquire suitable land upon reasonable terms by agreement, they were empowered to petition their county authority with a view to a provisional order being made authorizing them to acquire land compulsorily.

Land acquired by a sanitary authority under the Act of 1887 became subject to such regulations as to letting, cultivation, and general management as should be made by them with the approval of the Local Government Board, provided that such regulations did not contravene any of the provisions of the Act. No definite limit was laid down as to the amount of land that could be acquired by a sanitary authority, but the Act stipulated that one person should not hold any allotment or allotments acquired thereunder exceeding one acre. It was not permissible to sub-let any such allotment, and no building could be erected thereon other than a toolhouse, shed, greenhouse, fowlhouse, or pigstye. Allotment managers could be appointed by the sanitary authority with authority to exercise such of the powers possessed by them as they chose to delegate. One-sixth or more of the parliamentary electors for the parish could petition their sanitary authority to order an election of managers by ballot. If at any time any allotment could not be let in accordance with the provisions of the Act and the regulations then in force, the same could be let to any person upon the best rent obtainable, subject to such terms as would enable the sanitary authority to resume possession within a period not exceeding twelve months if the allotment should be required for letting under the provisions of the Act.

Allotments Act, 1890—The Allotments Act, 1890, contained provisions enabling petitions to be presented to county councils by not less than six parliamentary electors or ratepayers in the event of their sanitary authority failing to acquire adequate and suitable land for allotments. If on any such petition being presented the council, on enquiry, became satisfied that the circumstances were such that allotments should be acquired, it might pass a resolution to that effect, whereupon the powers and duties of the sanitary authority under the Act of 1887 were transferred to the county council except as to property acquired by the sanitary authority before the passing of the resolution. In such cases the county council could delegate powers of management to the sanitary authority, and, upon request of the latter, might transfer the property so acquired to them. The local Government Act, 1894, authorized local authorities to petition the Local Government Board for an order enabling them compulsorily to acquire land for allotments in the event of their county council having refused their petition for such an order, and the board might thereupon, should they think proper, make such order required.

ALLOTMENTS (*Continued*)—

Small Holdings and Allotments Acts, 1908 to 1926—The powers of local authorities for the provision and management of allotments were greatly extended by the Small Holdings and Allotments Act, 1907; this Act and the Acts of 1887 and 1890 were repealed by the Small Holdings and Allotments Act, 1908, which re-enacted their provisions in a consolidated form. The provisions contained in the consolidating Act of 1908 relating to allotments remain operative at the present day as amended and enlarged by the Allotments Acts, 1922 and 1925, and the Small Holdings and Allotments Act, 1926.

The Act of 1908 empowers the council of a borough, urban district, or parish, to provide allotments to the extent of 5 acres, but does not impose on them any obligation to provide allotments exceeding 1 acre. Such councils are also empowered to adapt land for allotments by erecting buildings and making adaptations to existing buildings, but so that not more than one dwelling house shall be erected for occupation with any one allotment, and no dwelling house shall be erected for occupation with any allotment of less than 1 acre.

The Small Holdings and Allotments Acts, 1908 to 1926, have given councils of boroughs, urban districts, and parishes extensive powers for raising money for the purposes of the Acts. Section 25 (3) of the Act of 1908 reimposed the provision contained in the Act of 1887 precluding the acquisition of land for allotments by local authorities if the price or rent thereof was such that, in their opinion, the expenses of providing the allotments, excluding any costs in making public roads, would not be recouped out of the rents to be obtained therefrom. This was slightly modified by the Allotments Act, 1922. The provision of allotments, however, became a matter of political consequence, and by section 4 of the Allotments Act, 1925, councils of boroughs and urban districts are now permitted to acquire land for allotments, although the rents to be received therefrom are not calculated to cover expenses, provided they are of opinion that the expenses of their proceedings under the Allotment Acts, after acquisition of such land, will not exceed their receipts under those provisions by greater amount than will be produced by a rate of one penny in the pound.

The right of individuals to petition their county authority in the event of their local authority failing to provide suitable and adequate land for allotments provided by the Act of 1890 was not reinstated in the Act of 1908. The latter Act imposes a duty on county councils to ascertain the extent to which there is a demand for allotments in the several urban districts (other than boroughs) and rural parishes in their counties, or to which there would be such demand if suitable land were available, and if a county council is satisfied that land for allotments for any such district or parish should be acquired by them it is their duty to pass a resolution to that effect, whereupon the powers and duties of the council of the district or parish concerned are transferred to the county council, in similar manner as previously provided in the event of a petition by individuals establishing that such local authority had failed to provide adequate land for allotments, and the

ALLOTMENTS (*Continued*)—

county council may in similar manner delegate powers of management, or transfer the land acquired by them, to the local authority.

The council of an urban district or borough, county council or council of a county borough, desiring to purchase or hire land compulsorily for the purpose of allotments now submit to the Minister of Agriculture and Fisheries an order for acquisition of land. Any order so submitted is of no force until confirmed by the minister, and the minister may make such modifications to the Order as he shall deem fit. Parish councils desiring compulsory acquisition of land, however, must submit their case to their county council, and only in the event of the county council refusing to make the order desired and submitting it to the minister for confirmation are such parish councils entitled to petition the minister for such an order as the county council might have made. Provisions as to the compulsory acquisition of land are contained in Part 1 of the first Schedule to the Small Holdings and Allotments Act, 1908. An order made under the Acts may not authorize the compulsory acquisition of land forming part of a park or garden, land required for the amenity or convenience of any dwelling house, land which is woodland not wholly surrounded by or adjacent to land acquired by a council under the Allotments Acts, and certain other lands. In making and confirming any order as aforesaid, the council and minister respectively must avoid taking an undue or inconvenient quantity of land from any one owner or tenant, and also, so far as practicable, avoid displacing any considerable number of agricultural labourers or others employed on or about the land. No order may be made for the compulsory hiring of pasture land if it be proved to the satisfaction of the minister that arable land reasonably suitable for the purpose of allotments is available for hiring.

Allotment wardens under the General Inclosure Acts, having the management of land appropriated under such Acts for the labouring poor, may, by agreement with the council of the borough, urban district, or parish in which such lands are wholly or partly situate, transfer their management to such council upon such terms and conditions as may be agreed upon with the sanction, as regards the allotment wardens, of the Minister of Agriculture and Fisheries, and thereupon such land vests in the council and is held by the council in like manner as if such land had been acquired by them under the Allotments Acts.

All matters relating to the exercise and performance by a county council of their powers under the Small Holdings and Allotment Acts, 1908-1926, with regard to allotments are referred to a Small Holdings and Allotments Committee, and a council may delegate to such Committee any of their powers under the Acts except the power of raising a rate or borrowing money.

Compensation for Crops, Provision for—The Allotments and Cottage Gardens Compensation for Crops Act, 1887, was the first statutory enactment particularly relating to compensation to occupiers of

ALLOTMENTS (*Continued*)—

allotments and cottage gardens for crops left in the ground at the end of their tenancies. By this Act a tenant of an allotment was entitled, notwithstanding any agreement to the contrary, to obtain compensation from his landlord, upon the termination of the tenancy, for crops, including fruit, growing upon the holding in the ordinary course of cultivation, labour expended upon and manure applied to the holding since the taking of the last crop therefrom in anticipation of a future crop, and for fruit trees and bushes, drains, outbuildings, pig-sties, fowl-houses, or other structural improvements supplied to the holding by the tenant, at his own expense, with the written consent of the landlord. The Act of 1887 was repealed by the Allotments Act, 1922; Section 3 (5) of the latter Act has, however, re-enacted the provision contained in the Act of 1887 with respect to allotments not exceeding 2 acres and not being allotment gardens, with the omission of the limitation of compensation for labour and manure to that expended since the last crop in anticipation of a future crop. The amount of compensation payable is determined, in default of agreement, by valuation, and in the event of the parties failing to agree upon the appointment of a person to make such valuation the appointment may be made by the Judge of the County Court having jurisdiction in the place where the land is situated, on an application in writing being made for the purpose by either the landlord or the tenant.

The Agricultural Holdings Act, 1923, applies to holdings which are either wholly agricultural or wholly pastoral, or in part agricultural and as to the residue pastoral. The Act does not, however, apply to holdings held in virtue of an office or employment held of the landlord, or to "allotment gardens." By virtue of Section 25 of the Act re-enacting Section 28 of the Agricultural Act, 1920, twelve months' notice is required to terminate the tenancy of an allotment to which such Act applies. Tenants of allotments not exceeding 2 acres, not being allotment gardens, may elect to claim compensation for improvements either under the Agricultural Holdings Act, 1923, or under section 3 (5) of the Allotments Act, 1922. (For compensation under the Agricultural Holdings Acts, see Improvements.)

Allotment Garden, Definition of—An allotment garden is defined by the Allotments Act, 1922, as "An allotment not exceeding forty poles in extent which is wholly or mainly cultivated by the occupier for the production of vegetable or fruit crops for consumption by himself or his family." Where land is used by a tenant as an allotment garden, such land is deemed to be let to him for such purpose unless the contrary is proved. The obligation of councils of boroughs and urban districts to provide allotments is now restricted to the provision of allotment gardens not exceeding 20 poles in extent if the population of such borough or district is ten thousand or upwards; such councils have to appoint allotment committees if the population of their district is of this extent, or the total number of allotments provided by them exceeds four hundred. Any person

ALLOTMENTS (*Continued*)—

causing damage to an allotment garden, or the crops, buildings, or fences thereon, by an act without lawful authority, or by negligence, is liable on summary conviction to a penalty not exceeding £5, provided a notice of the provision to this effect, contained in Section 19 of the Allotments Act, 1922, is conspicuously displayed on or near the allotment garden.

Termination of Tenancy, Conditions determining, and Compensation claimable upon—Section 1 of the Allotments Act, 1922, provides that where land is let on a tenancy for use by the tenant as an allotment garden or is let to any local authority or association for the purpose of being sub-let for such use, the tenancy of the land shall not be terminable by the landlord by notice to quit or re-entry, notwithstanding any agreement to the contrary, except by—

(*a*) six months or longer Notice to Quit expiring on or before the sixth day of April or on or after the twenty-ninth day of September in any year; or

(*b*) re-entry, after three months' previous notice in writing to the tenant, under a power of re-entry contained in or affecting the contract of tenancy on account of the land being required for building, mining, or other industrial purpose, or for roads or sewers necessary in connection with any of those purposes; or

(*c*) re-entry under a power in that behalf contained in or affecting the contract of tenancy in the case of land let by certain public undertakings on account of the land being required by the corporation or company for any purpose for which such land was acquired or appropriated under any statutory provision (not being the use of the land for agriculture), but so that, except in a case of emergency, three months' notice in writing of the intended re-entry be given to the tenant; or

(*d*) re-entry under a power in that behalf contained in or affecting the contract of tenancy, in the case of land acquired under the Housing Acts, 1890 to 1921, prior to the Allotments Act, 1922, let by a local authority on account of the land being required by the authority for the purposes of those Acts, and, in the case of other land let by a local authority, after three months' previous notice in writing to the tenant on account of the land being required by the authority for a purpose for which it was acquired or appropriated under any statutory provision (not being the use of land for agriculture); or

(*e*) re-entry for non-payment of rent or breach of any term or condition of the tenancy, or on account of the tenant becoming bankrupt or compounding with his creditors, or, where the tenant is an association, on account of its liquidation.

The foregoing provisions as to termination of tenancies did not affect notices to quit or proceedings for recovery of possession given or commenced prior to the passing of the Allotments Acts, 1922, and the provisions do not apply to land held by or on behalf of the

ALLOTMENTS (*Continued*)—

Admiralty, War Department, or Air Council, so let as aforesaid, where possession of the land is required for naval, military, or air force purposes.

No compensation for improvements is payable in respect of an allotment garden unless the tenancy is determined by the landlord and is so determined between the 6th April and 29th September in any year or by re-entry at any time under paragraphs *b*, *c*, or *d* of the preceding paragraph, in which cases compensation is recoverable from the landlord for crops growing on the land in the ordinary course of cultivation of the land as a market garden, and for manure applied to the land. Any sum due to the landlord for rent, or breach of the contract of tenancy, or for wilful or negligent damage committed or permitted by the tenant, is to be taken into account in reduction of the amount of the compensation.

A tenant of an allotment garden or an allotment under two acres may, before the termination of the tenancy, remove any fruit trees or bushes provided and planted by him, or for which he has paid compensation to an outgoing tenant, and may also remove any erection, fencing, or other improvement erected or made by and at his expense, or acquired by him, provided that he make good any injury caused by such removal.

J. D. M.

ALSIKE CLOVER—See Legumes, Breeding of Herbage.

ALUMINIUM—(Symbol Al; atomic weight 26·96; atomic number 13.) This element is found only in combination in nature, but is nevertheless the third most plentiful component of the earth's crust, of which it forms one-thirteenth part. The chief sources of supply are cryolite, mica, clay, felspar, and bauxite, but at present only the first and last are used to any large extent directly for extraction. Aluminium is also found in the ashes of plants in small quantities.

The metal is manufactured by the electrolysis of a solution of alumina in molten cryolite, a current as high as 20,000 amps. is often used at a voltage of 5 to 7 volts per cell, a series of forty to fifty cells being run from 260 volt mains. The production in Great Britain is at present stationary, while the demand is increasing. The metal is used to an ever-increasing extent in the manufacture of internal combustion engines, for cooking utensils, and in the canning industry, for fermenting vats in brewing, as also for barrel linings. In the dairy it finds its application in pasteurization apparatus, and for transport also many cheese vats are now made of it. It is also employed largely in jam factories, and has an important use in welding, since a mixture of iron oxide and aluminium powder can be ignited, and burns with the evolution of heat sufficient to melt the surface of a casting on which it is placed, and at the same time the oxygen is taken from the iron by the aluminium to form alumina, and the pure molten iron left is incorporated with the welding, improving its malleability. The large use of the metal in food preparation is due to the non-poisonous nature of its salts.

ALUMINIUM (*Continued*)—

Line (*J. Agric. Sci.*, xvi., 338, 1926) has recently shown that the "toxic aluminium" theory of acid soils is untenable; depression in plant growth only follows in cases where a hydrogen ion concentration harmful to the particular plant is reached and maintained during the growing period, and the beneficial effect of lime and phosphatic dressings is due solely to their action in reducing acidity. Calcium aluminate is in no case formed. (See Elements, Chemical.)

AMMONIA—Chemical formula NH_3. A pungent gas, more soluble in water than any other known substance, 1 volume of water at 0° C. dissolving almost 1,200 volumes of ammonia. It is, indeed, as the aqueous solution that it is usually met with in commerce. This has been thought to contain the hydroxide of the hypothetical group NH_4 called ammonium, of which a mercury amalgam can apparently be prepared, but the evidence for the existence of this hydroxide NH_4OH is not too convincing. The gas may be prepared by the dry distillation of salts of ammonium with slaked lime $Ca(OH)_2$. It is as its salts that it is of the greatest importance in agriculture. The sulphate, a well-known fertilizer, is obtained from gas liquor, and also to a great extent synthetically by the Haber process and otherwise. The chloride and nitrate are also largely employed (for further particulars see Nitrogen, Fixation of.) Salts and derivatives of ammonia are also present in considerable quantities in ordinary farmyard manure and in guano (*q.v.*).

AMMONIUM CHLORIDE—See Fertilizers.

ANEMOMETER—An instrument for measuring wind velocity. The best, such as the Dynes instrument, are constructed on what is called the Pitot-static principle—that is, the difference between the pressure in a tube closed at one end and with its open end towards the wind, and that in a tube of the same type subject only to the static pressure at the time is measured. From this the speed can be computed. For ordinary agricultural work the hemispherical cup anemometer is still largely used; its constant varies with the wind speed, and gusts are not recorded accurately even in the electrical type, in which the hemispherical vanes turn the armature of a small dynamo, the rate being estimated from the voltage recorded. The portable anemometer, with flat vanes rotating on a spindle in jewelled bearings, is better in both these respects. For air speeds less than 5 ft. per second, the only effective instrument is an electrical one, depending on the alteration of the rate of cooling of a hot wire with changes in the velocity of the air stream.

ANGELICA (*Archangelica officinalis*)—The stems and parts of the leaves of this plant are used by the confectionery and other trades in Great Britain, although on the Continent it is often consumed as a vegetable either in a raw or a cooked state. Quantities of angelica are grown around London as a market garden crop to supply the demand.

ANGELICA (*Continued*)—

It is a large, leafy plant which requires the moist conditions suitable for the celery crop. Although, strictly speaking, a biennial, angelica will live for three or four years if the vegetative portions of the plant are cut down during May or June in time to prevent their running to seed. A second crop will then be produced for reaping in early autumn.

The angelica crop should be raised by sowing the seed in a prepared seed bed in July or August. Plenty of water may be required to keep the seedlings moist, which, when large enough, should be set out on good, cool land about 2 ft. apart each way. Stalks from these plants will be fit for market during the following year.

APPLE—For dessert, culinary, and cider apples see Hard Fruit, under Fruit; also Refrigeration.

APRICOT—See Stone Fruit, under Fruit.

ARSENIC—(Symbol As; atomic weight 74·96; atomic number 33.) A metalloid element, of importance in agriculture only in combination. One of the oxides, As_2O_3, is used in the preparation of rat poisons, and certain salts, chiefly of sodium, lead and copper, in which arsenic occurs in the acid radicle, are used in spraying, etc., as insecticides and fungicides. (See Insecticides and Fungicides; Glasshouse Crops.)

ARSINE—A compound of arsenic and hydrogen (AsH_3), with a peculiar unpleasant smell not unlike onions or garlic. It is very poisonous to inhale.

ARTESIAN WELL—A well sunk through an impermeable layer of rock or clay into a water-bearing stratum. The water then rises in the tube to such a height as will balance the hydrostatic pressure in the permeable strata, sometimes so high, indeed, as to well out at the surface, as in many in London bored through the impervious London clay to the underlying chalk connecting with catchment areas both north and south of the Thames. They have been sunk up to 2,500 ft. deep, rocks being pierced by very costly diamond drills. The surface of the pipe formed on drilling has to be protected with iron or porcelain to prevent leakage of surface drainage into the well water. (See Water and Water Supplies.)

ARTICHOKE—The Jerusalem artichoke belongs to the Natural Order Compositæ, and is thus related botanically to the sunflower. In Britain it rarely flowers, except in very hot summers, but when formed the flowers are similar to those of the sunflower. It is a crop that can be easily grown, but, on the other hand, when once cropped on a piece of land it may become difficult to eradicate. For this reason it is usually cultivated on waste land, or on soils of poor character. The artichoke grows to best advantage on light rather than heavy soils, because of the greater facility in harvesting its tubers.

Artichokes, like potatoes, are propagated vegetatively from tubers, and the preparation of the seed bed should be carried out in a manner similar to that adopted for the latter crop. The land, after ploughing in winter, should be cultivated and worked down in spring; afterwards

ARTICHOKE (*Continued*)—
furrows should be struck 24 to 30 ins. apart, and the tubers dropped about 18 ins. apart in the furrows.

The tubers should be covered by splitting the furrows, and, subsequently, during early stages of growth the crop should be deeply cultivated between the rows and hand-hoed to keep down weeds. Later, when the plants have started to grow well, their leaves form a dense shade and smother weeds completely.

Artichokes should be manured with farmyard manure at the rate of 12 to 15 loads per acre, and a dressing of 1 cwt. of sulphate of ammonia and 3 cwts. of superphosphate at planting.

The usual method of harvesting small quantities for the vegetable market is to dig them by hand. The tubers are carried at the end of rhizomes, but at longer distances from the plant than in potatoes; consequently they cannot be so easily lifted with the "digger," although this implement is sometimes used. Occasionally, artichokes are grown on sandy land for pig food; in this case the pigs may be allowed to "rootle" out the tubers for themselves, or they may be ploughed out for the pigs to pick up.

The yield of this crop is variable, for it depends largely on the character of soil on which it is grown and on the manuring. On land in good heart, crops of 16 tons per acre have been obtained. The general range of yield is probably between 8 and 20 tons per acre.

The artichoke has sometimes been suggested as a suitable crop for silage, but the stems are too woody for this purpose. (For composition and feeding value see Feeding Stuffs; for cultivation as a culinary vegetable and for Globe Artichoke see Market Gardening.) A. A.

ASH (**Chem.**)—The result of calcining any animal or vegetable matter, whether previously metamorphosed or not, at a temperature so high that all carbon is completely oxidized, but not so high as to cause fusion. The term is often applied more generally to the result of any process of calcination even of pure metal, *e.g.*, magnesium. Chemical determinations of the composition of the ash of feeding stuffs are of importance in compounding a ration properly balanced as to mineral requirements. (See Metabolism, Mineral; for ash content of various feeding stuffs and mineral requirements of farm animals see Foods and Feeding; also Poultry Nutrition.)

ASPARAGUS—See Market Gardening.

ASSIMILATION—The transformation of a food material into the substance of a plant. The analogous process in animals is called digestion and resorption. Under the influence of sunlight the chloroplasts, *i.e.*, chlorophyll containing bodies in the palisade and mesophyll tissue of the leaves of plants, acquire the property of converting carbon dioxide into grape sugar and other carbohydrates used by the plant in building up its structure. The reaction has been thought to proceed in two stages, namely,

$$H_2CO_3 = H.CHO + O_2 \text{ followed by}$$
$$6.H.CHO = C_6H_{12}O_6 = \text{sugar,}$$

ASSIMILATION (*Continued*)—

but the actual process of the change is probably much more complex (see S. Kostytschew, "Lehrbuch d. Pflanzenphysiol.," i., 150-164). It appears to be the red rays that are chiefly efficacious in bringing about the change, the blue being more efficient than the yellow and green. This is physically comprehensible, as clearly the yellow and green rays are largely reflected from the green parts of the plant, and their energy is therefore of little use. It is from this building-up process in which light energy is transformed into chemical potential energy that coal, which is largely derived from plant tissues, has been called "bottled sunshine"—the heat given off in burning coal is a liberation of the sun's light energy stored up in the plant tissues tens of thousands of years ago.

Assimilation is a vital function of the internal tissues of the leaf (see Respiration). Chlorophyll alone is incapable of assimilating, so is a cell without chloroplasts, or a chloroplast containing chlorophyll but removed from the cell, or, again, a chloroplast which for some reason has not developed any chlorophyll. Like most biological processes, assimilation goes on best at a temperature of 37° C.

In other than green plants assimilation of carbon takes place by a different process known as chemosynthesis, in which it is stored by energy derived from the oxidation of ammonia or nitrites. Fungi, and parasitic and saprophytic plants generally, obtain their carbon already combined into more complicated organic substances.

Plants assimilate nitrogen usually by means of their roots in the form of nitrates. Those belonging to the order Leguminosæ have the ability to utilize atmospheric nitrogen direct, and even in these cases the statement should be modified, as the real fact is that the nodules on the roots are full of nitrifying bacteria living in symbiosis with their host, and any plant of another order could live in a similar way if it could only get itself infected with some similar organism to the *Bacillus radicicola* of legumes. Alders sometimes do this. Absorption of the soil salts into the plant roots not infrequently takes place through the medium of a fungal mycorrhiza, in which these may be changed and rendered more useful to the host.

Before leaving the matter of nitrogen assimilation, it may be mentioned that a not inconsiderable number of plants obtain nitrogen also by capturing small animals and digesting them in special receptacles often elaborated from leaves, as in *Nepenthes*. Indeed, it is not necessary to go to exotics to find examples, as the native sundews are all carnivorous, capturing their prey by means of the tentacles with which their leaves are furnished.

Little need be said of the assimilation of mineral substances which takes place in solution via the root, and water which enters largely by the same route is hardly assimilated at all, remaining as such in the plant structure, excepting to the small extent to which it is taken up in the production of carbohydrates.

This subject can hardly be treated effectively in the small space available here, and much of great interest has been unavoidably omitted. A short and interesting treatment is to be found in Stras-

ASSIMILATION (*Continued*)—

burger's "Textbook of Botany," pp. 213-234, London, 1912, while a full exposition of modern views on this interesting subject is to be found in S. Kostytschew's "Lehrbuch d. Pflanzenphysiol.," vol. i., pp. 82-289, Berlin (Springer), 1926.

ATMOSPHERE—The gaseous envelope of the earth (for its composition see Air). The lower layers of air are far more dense than those above, being compressed by the weight of those lying on top of them. The density falls off as we ascend, just like that of hay in a hay stack. The barometric pressure (p_h) at a height h may be computed approximately up to reasonable heights by means of the simple formula $p_h = p_0 e^{-0.2h}$, where h is stated in miles, and e is the exponential constant 2·71828 ... Not only the pressure, but also the temperature, falls on ascent; this follows no regular law for obvious reasons, but approximates to 1° F. for each 300 feet of ascent. All this applies to the *troposphere*—that is, the air up to about six miles above the earth. Beyond this point, out to the furthest limit of the atmosphere, variously estimated, but probably 100 to 120 miles above the earth's surface, the condition and properties of the highly rarefied mass of air are very different. This region, known as the *stratosphere*, is free from clouds, may quite possibly be of summery warmth, is windless, and falls in temperature as one moves from the equator towards the poles, but does not change in temperature with change of height, and consists to a large extent of nitrogen and hydrogen. This layer is rendered visible to us from the earth's surface on a fine day by the light scattered by the myriad motes of meteoric and volcanic dust which float there; it is, in short, the *blue sky*. It has been computed that the projection into this region of less than one cubic kilometre of volcanic dust, a not impossible event in the huge disturbances of cretaceous times, would have been sufficient to account for the ice ages owing to the reduction of the solar heat reaching the earth.

AVOCADOS—For methods of preservation by refrigeration see Refrigeration.

AWAY GOING—When an arable farm changes hands at Lady Day, there is frequently a growing crop of wheat which was sown by the outgoing tenant, and has to be paid for by the incoming tenant. A crop of this kind is always known as an away-going crop. The method of awarding compensation for an away-going crop varies greatly from district to district and county to county, but usually, under present-day systems of valuation, not more than one-fourth of the arable acreage of a farm may be considered as an away-going crop.

BAFFLES—Plates or meshes set up across a stream of gas or liquid with the object of preventing the establishment of definite stream lines of flow or to prevent eddy formation. A common example is the baffle found in malt kilns.

BALANCE—Strictly speaking, an instrument for comparing masses, but taking it in its usual wide sense it may be held to include weighing

BALANCE (*Continued*)—

machines of all sorts. Usually a balance consists of a lever of the first order, *i.e.*, one in which the fulcrum is between the weight and the power. To be valuable for accurate work a balance beam must remain horizontal whatever equal weights are placed in the pans; it must be sensitive to small differences in these weights; the period of oscillation must be small, and the beam must be stable, *i.e.*, it must return to equilibrium when displaced. Further, the sensitiveness should not differ markedly with change in the load. The first condition will be satisfied if the arms are of equal length, and if the centre of gravity of the beam is in the same vertical line as the fulcrum (centre knife edge) when the beam is horizontal, and if, in addition, the pans are of equal weight. It is worth remarking that a balance whose arms have been made accidentally unequal is not absolutely useless, since the true weight of an object may in that case be obtained by exchanging object and weights and reweighing; if the weight in the first case is w_1 and in the second w_2, the true weight is $\sqrt{w_1 w_2}$. To be sensitive a balance must have a long beam made of light material, and the centre of gravity of the beam must be only a very little below the centre knife edge. If the centre knife edge happens to be below the centre of gravity, the beam will be unstable, and will not return to equilibrium when unloaded. The conditions for the oscillation period to be small are that the centre of gravity should be a good way below the centre knife edge, and that the arms should be short, both of which are exactly opposite to the conditions for sensitivity; thus, a mean has to be struck, keeping in view the purposes for which the instrument is intended. A good elementary discussion of these points will be found in W. Watson's "Textbook of Physics," Longmans, pp. 100-105, 1911.

In well-made scientific balances an accuracy to 1 part in 100,000 may be looked for, and an accuracy as high as 1 part in 400,000 is claimed for the latest Collot-Longue balances weighing up to 20 kgs.

Microbalances capable of weighing to the millionth part of a gram and less have been constructed in recent years; in these the beam usually consists of a light silica framework in a vertical plane suspended by two quartz filaments attached horizontally in a plane at right angles to the frame, and which act as the fulcrum. The minuter portions of the weighing are taken against the torsional rigidity of these filaments, the effective weight of the counterpoise being altered by changing the density of the gas surrounding it.

The action of a spring balance depends on the law discovered by Hooke, that if a spiral spring of cylindric type extends by 1 centimetre when loaded with w grams, it will extend 2 centimetres when loaded with 2 w grams, 3 centimetres when loaded with 3 w grams, etc.; they are unsuited to accurate work.

One should note that an ordinary balance measures *mass*, while a spring balance measures *weight*. On the earth's surface their readings naturally agree, but if taken to the moon a pound of sugar would still weigh a pound on the ordinary balance, while on a spring balance it would only weigh about 2 ozs. 11 drms.

BALANCE (*Continued*)—

The different types of steelyards and weighbridges are modifications of the balance in which other physical principles involving the law of moments and parallel forces are employed. (See Weighbridges.)

BALANCE, CARBON AND NITROGEN—Body nutrients, protein, fat and carbohydrates, may be gained or lost from the body by the ordinary life processes of the animal. We cannot, however, measure the gain or loss of these substances directly, but have to rely upon estimations of intake and output of the elements carbon and nitrogen. When an animal is in such a state that the quantity of each of these two elements in the body is sensibly constant, the animal is said to be in carbon and nitrogen balance, and a statement set out in the form of a "balance sheet" showing income and expenditure of C and N under various headings is a convenient mode of illustrating the computations involved. The following balance sheet for a steer is taken from Armsby, "Nutrition of Farm Animals," p. 206.

	Nitrogen.		Carbon.	
	Income.	*Outgo.*	*Income.*	*Outgo.*
	Grms.	Grms.	Grms.	Grms.
6,988 grms. timothy hay ..	56·4	—	2,831·7	—
400 grms. linseed meal	21·9	—	172·6	—
16,619 grms. fæces ..	—	33·5	—	1,428·7
4,357 grms. urine	—	32·4	—	124·2
37 grms. brushings		1·3	—	8·0
4,730 grms. carbon dioxide				1,290·2
142 grms. methane				106·6
Gain by body ..				46·6
	78·3	78·3	3,004·3	3,004·3

This steer was, therefore, storing 11·1 grms. of nitrogen and 46·6 grms. of carbon, but the nitrogen was stored as $(11 \cdot 1 \times 6 \cdot 25)$ grms. of protein $= 69 \cdot 4$ grms. protein, which includes part of the carbon stored. Since protein contains 52·54 per cent. of carbon, we have therefore 36·4 grms. carbon stored as protein and the remainder $(46 \cdot 6 - 36 \cdot 4) = 10 \cdot 2$ grms. carbon stored as fat or carbohydrates. When the animal is being fed a productive ration, this may usually be assumed to be fat, but in submaintenance work hydrogen and oxygen balances may also have to be made. It is very difficult in practice to bring an animal into exact C and N balance, *i.e.*, to such a state that the gain or loss of each is *nil*, and in respiration work corrections have to be applied for slight excesses or defects in these figures. (See Calorimetry, Animal.)

BALK—The original meaning of balk is an unploughed strip lying between two ridges of land. It now means a drill or ridge used for planting potatoes or drilling certain root crops.

The term "balking" means setting land up in drills or ridges.

BANANA—The banana, with which must be associated the plantain, is the fruit of certain species of the genus *Musa*. Though native to

BANANA (*Continued*)—

the tropics, cultivated varieties are found in subtropical regions, and certain varieties are capable of withstanding considerable cold, as in the Himalayas, where the plant may be found at 5,000 ft. or even higher. Some variety is found throughout the tropics wherever adequate moisture is available; for the plant has no dormant period and, as a lover of humid conditions, thrives best where there is no sharply defined dry season. The natural home of the plant is the East, but tropical America and the West Indies is now a centre of commercial production of the banana. The plant reached the Canary Islands, which still remain a centre of production, in 1516, whence it was carried to America.

The genus is of the Old World and contains some twenty species. The species which yield edible fruit are two in number with an indefinite, but considerable, number of varieties. Both species belong to the sub-genus *Eumusa* (*Kew Bull.*, 1894).

M. Cavendishii Lamb. ex Paxt. is the dwarf banana, a native of Southern China, but widely cultivated especially in the Canary Islands and Australia.

M. sapientum L. is a tall plant also widely cultivated. It appears to be a native of south-east Asia (Harland, *Trop. Agriculture,* v., 1928), but the centre of commercial production of the fruit of this species is now tropical America and the West Indies. *M. paradisiaca* L. furnishes the plantain, and is usually considered a subspecies of *M. sapientum*. It, again, is widely cultivated, but has not the commercial importance of the banana. It is mainly grown as an adjunct to peasant or village holdings, and forms the staple food of many tribes in Central Africa. The numerous varietal forms of the banana have never been critically studied, and the synonymy requires to be unravelled. Howes (*Kew Bull.*, 1928) has investigated the forms found in the East, but little is known of the African forms of *M. paradisiaca.*

The banana plant is composed of an underground stem or "bulb," a tuberous rhizome, from which arises an aerial false or pseudo-stem, composed of the closely appressed leaf stalks. The bulb serves the function of a food reserve which is absorbed with the growth of the inflorescence or "bunch." With the ripening of the bunch the stem bearing it dies down, or, in cultivation, is cut back, and growth is continued by lateral offshoots, or suckers, from the bulb. The life of the individual plant is, thus, indefinite. Under cultivation, excess suckers are removed while new plantations are established by the removal and planting elsewhere of these suckers. The flowers are set in clusters, or "hands," on the bunch, each hand being subtended by a large bract. The earlier, or lower, clusters are composed of female, the later, or upper, of male flowers. In most cultivated forms the formation of seed is of rare occurrence.

The cultivation of the banana and plantain is conducted on two entirely different principles. In the one case, as in India, Central Africa, and generally throughout the tropics, it is associated with peasant cultivation; in the other, it is conducted on a plantation basis, and the fruit forms the basis of an extensive export trade (*Impl. Econ.*

BANANA (*Continued*)—

Com. Rep., iii., 1927). The agricultural problems centre around this latter type of cultivation. The main centres of production are:

1. America, Central, South (Colombia), and North (Mexico), and Jamaica. The variety here grown is, to the practical exclusion of all others, the Gros Michel, a variety of *M. sapientum*. The fruit is shipped to the United States, Canada, and Europe.

2. Brazil. Several varieties of *M. sapientum* as well as *M. Cavendishii* are cultivated and the fruit shipped to Buenos Ayres, and latterly to England.

3. The Canary Islands. These islands are the source of the European supply of the small-fruited *M. Cavendishii* (*Impl. Inst. Bull.*, xxiii., 1926).

4. New South Wales and Queensland. The Australian market is supplied from these areas of cultivation as well as from the Oceanic Islands, especially Fiji. The banana grown to the practical exclusion of all others is *M. Cavendishii*.

5. Formosa. This island is the source of Japan's supply.

6. The Philippine Islands and Hawaii. A large number of varieties are cultivated in these islands (Wester and Barrett, *Philip. Agric. Rev.*, v., 1912; Pope, *Hawaii Agric. Expt. Stat. Bull.*, 55, 1926). The crop is exported to the United States.

On the mainland of tropical America banana cultivation is essentially a form of exploitation. The virgin forest is cleared of bush, the timber felled, and the suckers planted. Once the plant is established no further cultivation is given. Under favourable conditions the plantation yields indefinitely, but frequently an unhealthy condition supervenes, and large areas formerly planted up have been abandoned. In Jamaica, as elsewhere, greater attention is paid to cultivation. The land is well prepared and, if virgin, the natural growth is cut and burned, and the stumps eradicated. Holes are prepared at about 15 by 15 ft., and suckers, preferable "maiden" suckers, *i.e.*, suckers about eight months old, with adult foliage as opposed to "sword" suckers, which are younger with narrow leaves, planted. Subsequent operations are directed to soil aeration and the maintenance of humidity by mulching. Green crops may be grown for this purpose, and, where necessary, irrigation is provided. For the development of a full bunch, which in the case of the Gros Michel must be of nine hands or over, or much of the value will be lost, not more than three suckers of graduated age are allowed to remain to each bearing stem.

The main banana plantations feed, as has been shown, an export trade which, from the perishable nature of the fruit, necessitates special handling. The fruit must be cut at a stage of maturity adapted to the length of the voyage, and, in the case of longer voyages, special provision for cool chambers is necessary. It is its especial adaptability to conform to these requirements which is responsible for the extended cultivation of the Gros Michel variety. Since the stem is strong and the fruit recurved, the bunches can be packed in the hold without further packing or support than is given by the baulks. The Canary banana (*M. Cavendishii*), on the contrary, with its soft and readily

BANANA (*Continued*)—
injured "peel," requires the separation and crating of the individual hands. It is this highly organized system of transport which has been built up on the special characters of the Gros Michel that has set a sharp limit to the field of economic investigation of the crop. Such an investigation has recently been forced on the industry by the serious ravages in recent years of the Panama disease, otherwise known as the Banana Wilt. (For transport see Refrigerator.)

Panama Disease first attracted attention in Panama and Costa Rica early in the century, and it has since been recorded throughout the areas where the Gros Michel is cultivated with the exception of Colombia. It has been quoted as the cause of the abandonment of extensive areas on the mainland of tropical America; it has caused serious loss to the plantations in Jamaica, while it put an abrupt stop to the development of the banana industry in St. Lucia (Walters, *Trop. Agric.*, vi., 3, 1929). With the disease is associated the fungus *Fusarium cubense* E. S. Smith. A very detailed study of the disease has been made by Brandes (*Phytopath.*, ix., 9, 1919). Reinking suggests that *F. cubense* is a facultative parasite, common as a saprophyte in tropical soils, which has adapted itself to a life of parasitism on the banana (*Phytopath.*, xvi., 6, 1926). The whole problem of the disease is now the subject of intensive study, and Wardlaw (*Ann. of Bot.*, 175, 1930) has made a detailed study of the biological aspects. From a survey of the banana areas of tropical America and the West Indies it is concluded (Wardlaw and McGuire, *Empire Marketing Board Rep.*, xx., 1929) that fundamentally the disease developed as the result of unfavourable soil conditions. The extensive planting up of virgin lands under the pressure of increasing demand has involved much land of unsuitable character. The replacement of the extensive system of exploitation by an intensive system of cultivation, with attention to aeration and the maintenance of a reasonable constancy in moisture conditions in the soil, will go far to bring the disease under control. It is the ideal nature of the conditions in Colombia that is responsible for the absence of the disease in that country.

It was early noticed that certain varieties of bananas, especially *M. Cavendishii*, and certain varieties of *M. sapientum*, among which may be mentioned the Lacatan, Congo, and Giant Fig, show a marked degree of resistance, amounting to practical immunity, to the disease (Ashby, *Trop. Agric.*, i., 11, 1924). Substitution of these, however, raises serious questions as to their suitability for transport. In addition to the points noted above there is the question of disease attacking the fruit while in transport (Wardlaw and McGuire, *Trop. Agric.*, vii., 7, 1930). Advantage is also being taken of the tendency for the occasional development of viable seed to raise crosses between the Gros Michel and resistant varieties (Editorial, *Trop. Agric.*, vii., 7, 1930).

In the East serious loss is caused by a disease of another type, so far confined to the eastern areas. It was recognized in Fiji in 1885 and in 1894 threatened the industry of that island. It has since appeared in Ceylon (1913) and Australia, where it wiped out the industry in

BANANA (*Continued*)—

north-east New South Wales and south-east Queensland in 1916. A disease thought to be the same is found in Egypt. The disease, which passes under the name of bunchy top, was originally supposed to be associated with the attacks of the nematode *Heterodera radicicola* Greaf. This supposition is reviewed by Gadd (*Trop. Agriculturist*, lxvi., 1, 1926). Work by Ocfemia (*Phytopath.*, xvii., 4, 1927) and in Australia (Magee, *Aust. Council of Sci. and Ind. Res. Bull.*, x., 30, 1927) indicates that the disease falls into the group of Virus Diseases not directly transmissible. In this case the agent of transmission is the Aphis *Pentalonia nigronervosa* Coquerel, while Ocfemia and Catinisan definitely conclude that there is no association between the disease and the nematode (*Phytopath.*, xviii., 10, 1928).

A detailed account of the banana and its cultivation in the different areas is to be found in Fawcett's book "The Banana." H. M. L.

BANDING (**of Fruit Trees**)—See Insect Pests of Fruit Trees and Bush Plants, under Fruit.

BARLEY—According to the Agricultural Census of Production of Great Britain and Northern Ireland, 1925, the area devoted to barley in that year amounted to 1,472,802 acres. In 1930 there were 1,136,146 acres, and the distribution of acreage in the two years was as follows:

	1925.	1930.
England	1,264,983	1,026,000
Wales	52,827	
Scotland	152,921	107,000
Northern Ireland	2,317	2,146

The acreage of barley in the Irish Free State is approximately the same as that found in Scotland.

The barley acreage is thus of the same order as that devoted to wheat, and these two crops together comprise less than the total devoted to oats by 90,000 acres.

The importance of the barley acreage relative to that devoted to other cereals is seen in the following figures, which show the distribution per 100 acres of tillage in 1925:

	Wheat.	*Barley.*	*Oats.*
England and Wales	18·5	16·3	23·0
Scotland	2·8	8·9	53·7
Northern Ireland	0·6	0·4	55·2

As in the case of wheat, the barley acreage has been subject to a persistent decline since 1871-75, at which time there were 2,115,000 acres, to 1925 with 1,318,000 acres, a decrease of 797,000 acres.

A concomitant effect of the economic conditions responsible for a diminution of acreage of such proportions is the localization of the remaining acreage to portions of the country where, for various reasons, the crop can still be produced profitably. Thus, an examination of acreage distribution on a geographical basis shows that in England—the largest contributor to the total output—the densest acreage of barley is in the eastern counties of Norfolk, Suffolk, Cambridge, and Rutland. Following these counties the next in importance are Essex,

BARLEY (*Continued*)—

Lincoln, Yorkshire, Oxford, and Northampton. Succeeding, and excepting for a few north-western and midland counties, and including Cornwall, Surrey, and Sussex, there is a very general but less intensive acreage in the remaining counties. (Fig. 3.)

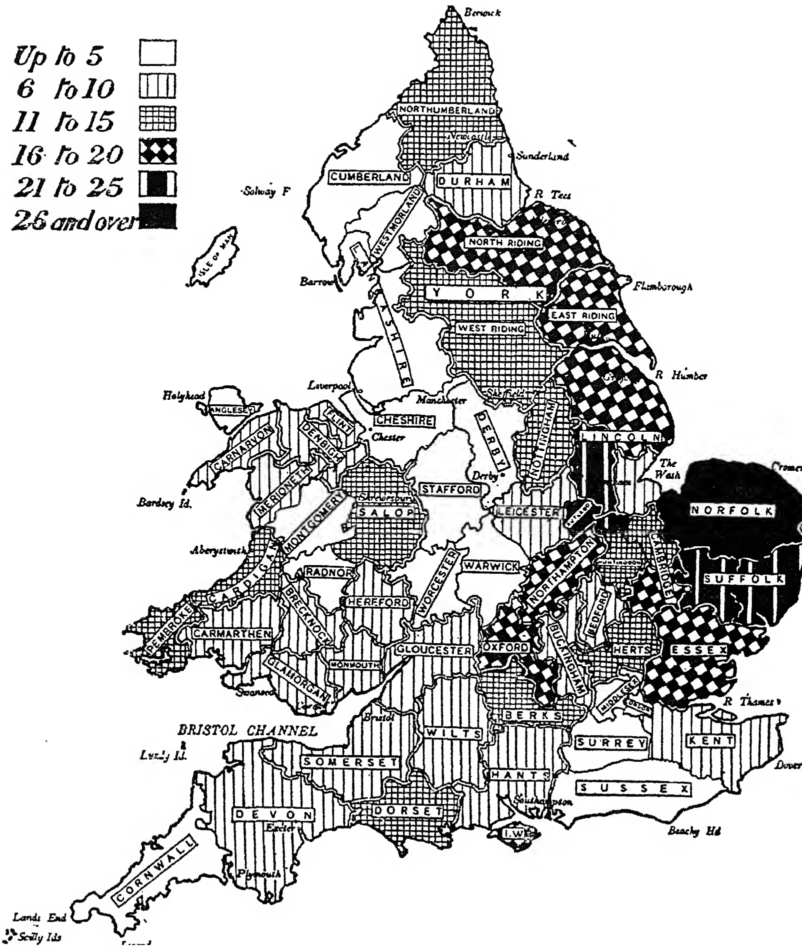


FIG 3.—SHOWING NUMBER OF ACRES OF BARLEY PER 100 ACRES OF ARABLE LAND IN 1925.

(From "The Agricultural Output of England and Wales, 1929," Ministry of Agriculture and Fisheries, by permission of H.M. Stationery Office.)

A study of the conditions accountable for the large area of barley found in Norfolk—namely, 199,000 acres, or 15 per cent. of the total acreage of England, leads to the conclusion that in a dry climate and

BARLEY (*Continued*)—

on light to medium soils this crop finds its most suitable environment. A conclusion stated in such terms is, however, only partially true, since it ignores the important fact that amongst varieties in cultivation there are some, mostly confined to the broad-eared class, to be described later, that can be successfully grown on medium to fairly heavy soil. Further, barley is cultivated on a fairly large scale in Ireland, where the annual rainfall is frequently double that of Norfolk; the average yield of grain per acre in that country is, indeed, considerably higher than the average for England, but the crop is grown on light to medium loams, all possessing subsoils capable of sustaining a good natural drainage.

It may be stated, consequently, that with the reservation as to variety, barley is best suited to light, well-drained soils and light loams, and, provided the soil is efficiently drained, to all but the more northerly and colder districts of the British Isles. Its almost complete absence from Northern Ireland and north-west England is thus a significant feature.

Supplies—The total supplies of home-grown and imported barley utilized in the United Kingdom during recent years had been much less than formerly. In 1925, 1926, and 1927 the figures were 1,944,000, 1,605,000, and 1,778,000 tons respectively, the diminution of supplies being common to both home-grown and imported grain.

On the average of the five years 1923-27, 44 per cent. of the total supplies were imported, Empire supplies representing 28 per cent. of the imported and about 12 per cent. of the total supplies (*Min. Agric. and Fisheries,* "Rept. on Marketing of Wheat, Barley, and Oats," Econ. Ser., No. 18, 1928).

Utilization of the Crop—In the British Isles barley is produced mainly with the idea of its being purchased and utilized for malting, for which purpose it must reach a standard of quality determined by the special requirements of that process. In England there is a wider difference in price between what is regarded as good malting barley and barley which fails to reach this malting standard than exists on a quality basis for either of the other two main cereals. This position, coupled with the fact that only three-fifths of the total native produce is utilized in brewing and distilling, focusses particular attention on the malting quality of the grain. The physical appearances of good malting barley are very definite; thus, a section taken through the grain about midway between the base and the tip of the corn shows that it is approximately circular; the furrow is almost completely filled, and the skin of the corn is very finely reticulated; in samples secured free from weather effects the skin also bears a delicate bloom. These are attributes of the grain itself, but a sample of barley must, before it is acceptable to the maltster, be characterized also by high "condition," evenness in size, and freedom from weed seeds and other foreign matter. Further, it must not exhibit evidences of careless threshing, such as cracked grain, or the removal of the germ or any portion of the skin.

BARLEY (*Continued*)—

There is no difficulty in discriminating between samples exhibiting the extremes of malting quality, but the greater portion of the barley is of an intermediate quality, and here determination of value or physical appearance cannot be made so readily. For this reason there arose the necessity for supplementing the estimation of malting quality on a physical basis by a chemical basis which would permit of comparisons of quality of grain produced under varying conditions of soil and climate, and between that of different seasons. The process of brewing is essentially the production of a solution of various carbohydrates which are capable of undergoing fermentation when acted upon by yeast. It consequently follows that the value of a sample of barley for brewing depends to a very large extent on the amount of carbohydrate material it contains. But the two principal organic substances found in cereal grains are carbohydrates and proteins, which vary inversely in respective amounts; the value of a sample may thus be regarded as varying inversely as the nitrogen content, or, in other words, the lower the total nitrogen the higher the carbohydrate content, and consequently the greater the extract obtained on brewing.

Malting, which is the initial process in the production of beer and spirituous liquors, consists of germinating the grain and permitting its growth to proceed to a stage at which the walls of the cells enclosing the starch grains of the endosperm are dissolved by the enzyme, cytase. Further development is then stopped by kiln-drying, and the next stage, the conversion of the starch into soluble sugars, is brought about by the action of diastase in the mash tun.

Barleys of good quality malt readily and fully, and in a minimum time, and finally yield a large extract; they are also characterized by a low total nitrogen content. Barleys of poor quality, on the other hand, do not malt easily, and produce a relatively low extract; their total nitrogen content is almost invariably high. In barleys of the highest malting quality the total nitrogen content varies from 1 to 1·3 per cent. of nitrogen; in barleys described as good quality this figure varies from 1·3 to 1·5 per cent.; whilst those with from 1·5 to 1·75 per cent. are approaching a border line of malting quality; above 1·75 per cent. the grain is unsuitable for ordinary malting.

The total nitrogen content thus forms a valuable criterion of malting quality, and modern researches have been directed mainly to the study of the conditions which influence the amount of protein present in the grain. Briefly, these have been found to be (*a*) the climate; (*b*) the soil, its physical condition and its fertility; (*c*) the variety; (*d*) the degree of ripeness at time of cutting; (*e*) a series of conditions such as the time of sowing, the character of the seed-bed, the weather immediately before and after sowing, etc., and, finally, the character of the seed.

Each of these influences will be dealt with in some detail later, and it will then be realized that although the weather, and to a lesser degree the soil, may together exert a determining influence on final quality, in the choice of variety and in the exercise of good husbandry the farmer does possess the means of a considerable measure of control.

BARLEY (*Continued*)—

Although the relation of total nitrogen content and malting quality is so close as to be almost synonymous, one or two cases of deviation from the general rule have been recorded. They are, perhaps, more noticeable by reason of their rarity, but their occurrence indicates the possibility of the constitution, rather than the total quantity, of the protein being a determining character.

The total nitrogen content of the grain as an index of quality has proved remarkably useful in differentiating between the many selections of hybrid families, where the quantities of grain available are severely restricted but the number of selections is very large. To increase even a very limited number of these to a stage at which their values can be ascertained by a malting test is a proceeding involving a large expenditure of time. By using the total nitrogen content as an index of quality, to be supplemented later if necessary by actual malting trials, breeding procedure has been materially expedited.

There is a voluminous literature bearing on the subject of malting quality in barley, much of which is contained in the Journals of the Institute of Brewing. Reference should also be made to a paper entitled "Researches on the Germination of some of the Gramineæ," by Horace T. Brown and G. Harris Morris, *J.C.S.*, vol. lvii., 1890. (For use as animal foodstuff see Foods and Feeding; and Feeding Stuffs.)

Botanical—Of the different aspects of the improvement of the barley crop, none has received more attention within recent years than the question of variety, and the sifting of the good from the inferior varieties, supplemented by a critical study of the peculiarities and potentialities of superior forms and an attempt to ascertain the most suitable environment for each variety, has benefited the grower and maltster alike. It will not be inappropriate, therefore, to present the variety question in some detail.

There is an extraordinary diversity of forms found under the genus *Hordeum*, the features differentiating them being colour of the paleæ, colour of the caryopsis, adherence or non-adherence of the paleæ to the caryopsis, the character of the awn, density of the ear, and the degree of fertility of the spikelets composing the ear.

Amongst British varieties the awn is regarded as normal, *i.e.*, it is straight, and elongated to about sixteen times the length of the grain; the paleæ are fused with the caryopsis, consequently there are no naked-grained sorts, and the major botanical differences are grouped around the degree of fertility and the density of the ear.

The fully fertile ear of barley consists of six rows of single-flowered spikelets, and all varieties of this character are described as six-rowed.

The next large group to be considered here is that in which there are only two rows of single-flowered spikelets, and four rows of staminate or infertile florets; this is the two-rowed group. Between these two main groups there is another in which the medium rows of florets are fully developed, and the four lateral rows are developed, but the florets are much smaller than those of the medium row; this is the intermediate group.

BARLEY (*Continued*)—

Finally, there is a group in which there are no lateral florets and only the medium florets are developed, and these are of normal size.

Following this differentiation of species on a basis of fertility, each group may be further divided according to the density of the ear, *i.e.*, the length of the internode, or the distance between the nodes of the rachis from which the florets arise. Those in which the internodes are short are termed dense, whilst those with long internodes are described as lax; between these two there is a further group comprised of forms of intermediate density.

The varieties commonly cultivated in this country are all white-grained, and in all the paleæ are fused with the caryopsis. There are a few six-rowed forms, some dense and some lax-eared (*Hordeum hexastichum* and *H. vulgare*), and still fewer belonging to the intermediate class (*H. parallelum*). Many of these are winter sorts, others are early ripening spring sorts, but with very few exceptions they fall below the two-rowed varieties in malting value.

The bulk of the barley grown in the British Isles belongs to the two-rowed group (*H. distichum*), in which a division on the basis of density of ear occurs again—the densest ears being found under *H. zeocrithum*, ears with intermediate density under *H. erectum*, and the lax-eared forms under *H. nutans*.

Cultivated Varieties—One very salutary improvement effected in the barley crop in recent years has been the limitation of the number of varieties in use, and to-day, largely as the result of experimental work conducted first in Denmark, then in Ireland, and lastly in England, there are only six varieties in extended use in the British Isles, and consequently of sufficient economic importance to merit comment here. These are Spratt (*H. zeocrithum*), Goldthorpe, Plumage, Plumage-Archer (*H. erectum*), Archer and Spratt-Archer (*H. erectum* or *H. nutans*).

Spratt is noteworthy because, amongst other things, it is one of the old English barleys. It exhibits a distinct partiality for soils containing a large amount of organic matter, and is still in cultivation in the Fen districts, although on a much smaller scale than formerly. The straw of Spratt is remarkably stiff and erect, and on suitable soils the yield of grain is decidedly high, but the appearance and malting quality of the grain are inferior to those of several newer broad-eared types.

Archer, like Spratt, has been cultivated in England for a long time; its origin is obscure, but it was formerly grown extensively in the south-east of England. It is a variety of high-yielding proclivities, and the grain, although somewhat less well-coloured than some introductions of more recent times, is usually of good malting quality.

Goldthorpe is a broad-eared barley of comparatively recent introduction; it is prolific and the straw is abundant and stands well, but the ear is very liable to become detached therefrom on ripening. The malting quality of Goldthorpe probably marks the highest standard yet reached by British barleys.

BARLEY (*Continued*)—

Plumage is a broad-eared variety of Danish origin. In all characters it resembles Goldthorpe closely.

In cases where the quality of a product is of such paramount importance as it is in barley, it is essential that a consideration of this attribute should proceed concurrently with investigations on the more purely agricultural side. In Denmark, in the case of the investigation already referred to, this was achieved by the co-ordination of field experiments with malting trials carried out by the Carlsberg Brewery of Copenhagen; in Ireland, by collaboration on similar lines with Messrs. A. Guinness, Son and Co., Ltd., Dublin; whilst in England the National Institute of Agricultural Botany have secured the assistance of the Research Committee of the Institute of Brewing.

Prior to these investigations, barleys of the Chevallier type were the most widely cultivated sorts, but broad-eared forms were beginning to attract attention.

The Danish experiments demonstrated the superiority of Archer* to all forms of Chevallier in point of yield of grain, but the valuation of samples on the old empirical basis of physical appearance resulted in the former being allocated a position of inferiority in the scale of values to other less productive but more attractively coloured sorts. When the field comparisons were viewed in conjunction with those obtained from actual malting trials, however, Archer produced the largest quantity of brewer's extract. It is also interesting to note that although the physical appearance of the grain was not equal to that of some other varieties, its total nitrogen content bore a close relation to the malting results.

In Ireland the earlier results obtained in Denmark were substantiated to a remarkable degree, whilst more recently Spratt-Archer and Plumage-Archer were shown to be the most remunerative varieties both in that country and in England (*J. N. I. A. B.*, No. 6, 1927).

The net result of these three sets of investigations has been the virtual elimination of barleys of the Chevallier type and their replacement by Spratt-Archer, whilst Plumage-Archer has practically replaced all the broad-eared types.

A further result has been to demonstrate, *inter alia*, distinct differences in the malting quality of varieties, a finding that has been shown by breeding tests to have a genetical basis in the quantity of total nitrogen in the grain.

Plumage-Archer and **Spratt-Archer** owe their origin to attempts to supplement the advantages gained as a result of the Danish and Irish work. As already mentioned, there is little doubt that Goldthorpe is one of the very best malting barleys in existence, but it suffers loss in the field by the ears breaking off the straw—a defect to which Archer is not subject.

* In Denmark, Archer is known as "Prentice barley" by reason of the fact that an English seedsman of the name of Prentice supplied the original lot of Archer barley imported into Denmark in 1881. The identity of Archer and Prentice was pointed out by Mr. Alan McMullen, "Barley Cultivation in Ireland," 1909. See also "Barley Cultivation in Denmark," *J. Dept. Agric. and Tech. Instruction, Ireland*, Oct., 1914.

BARLEY (*Continued*)—

By crossing Plumage, which is a type of Goldthorpe, with Archer, Dr. E. S. Beaven was successful in raising Plumage-Archer, a broad-eared variety no longer subject to the losses previously sustained by Goldthorpe, and at the same time retaining the excellent malting qualities of that barley associated with high grain-yielding potentiality.

Following the successful performance of Archer in the Danish and Irish investigations, this barley was grown on a larger scale in Ireland, with beneficial results to both farmer and maltster. It exhibited two defects, however: it was somewhat late in ripening, and in seasons characterized by abundant vegetative development the straw was inclined to become "lodged." Archer was accordingly crossed with Spratt, and, from the progeny of the hybrid, a narrow-eared form with what appeared to be stiffer straw than Archer was selected.

Spratt-Archer, as the new barley was named, also proved subsequently to be more prolific, slightly earlier, and of rather higher malting quality than the parent Archer (H. Hunter, "The Barley Crop," E. Benn, Ltd., London, p. 110 *et seq.*).

It is somewhat difficult to assess the enhanced value of these new varieties to the farmer, but judging by the Irish experiments, which from 1901 to 1906 included the then widely grown Chevallier, the improved yield of Spratt-Archer is equivalent to 11 bushels per statute acre. The gradual rise in the average yield of barley shown by the official returns since 1908 gives credence to this figure.

Proceeding to a consideration of the effect of this work on the quality of the grain: this is still more difficult to arrive at, for although the maltster and brewer may be conscious of improvement, they are in the position of having to discriminate between a true varietal influence and one to which the character of the season may be largely contributory. So far as the total nitrogen content is an adequate criterion, there is evidence, in the results of comparative trials, of a gradual reduction as a change is made, first, from the old Chevallier types to Archer, and then from Archer to Spratt-Archer. In the same way Goldthorpe exhibits a distinct advance on Standwell—the broad-eared type in cultivation twenty-five years ago. Thus, taking the Irish figures, twenty-five comparisons of Archer and Chevallier were made in three years, and the average total nitrogen of the grain was as follows:

Archer	1·54
Chevallier	1·63

In 1919 to 1923 thirty-nine comparisons of Archer and Spratt-Archer were made, and the average total nitrogen for this series of tests was:

Archer	1·59
Spratt-Archer	1·52

Similarly in twenty-four comparisons of Goldthorpe and Standwell, conducted in four years, the average nitrogen was:

Goldthorpe	1·55
Standwell	1·64

BARLEY (*Continued*)—

That there is an appreciable difference in the behaviour of varieties of barley on the malt floor is a fact well known to maltsters, and in consequence barley buyers now insist on bulks of grain being pure, *i.e.*, they must consist wholly of one variety. The greatest difference in behaviour on malting is found between broad and narrow-eared sorts, but as there are differences in the total nitrogen content in the varieties of both classes the best malting results are obtainable when not only the two sorts but the varieties of each sort are malted separately. In Ireland pure line cultures, *i.e.*, bulks of seed raised in the case of each variety from a single ear or plant of that variety, were tested against unselected stocks of each variety, and the former possessed an appreciable advantage both in the field, and subsequently in the malthouse. The grain of the pure line stocks exhibited a marked improvement in evenness in size and in degree of ripeness, both attributes commanding the appreciation of buyers (H. Hunter, "A Summary of Experiments in Barley Growing conducted during the Eleven Years 1901-1911," *J. Dept. Agric. Tech. Instruction, Ireland*, vol. xiii., No. 1).

Weather—In addition to the effect of variety on the malting quality of the grain there is the very much more potent influence of the weather. For the production of malting barleys of the character desired in the British Isles, and when dealing with such varieties as, on the basis of yield, quality, and other features, are most appropriate for the various conditions involved, a climate characterized by moderate temperature and not excessive rainfall is the most suitable. Although a plentiful supply of moisture in May and June, *i.e.*, during the period of maximum vegetative developments, is highly important, especially in regard to the yield of the crop, it is the conditions obtaining during the final stages of grain filling and ripening that largely determine the ultimate quality of the grain. If the weather at that period is unduly hot, the plant tends to die prematurely as a result of an insufficient supply of moisture, rather than in consequence of the completion of the transference of material from the straw to the grain. When, on the other hand, the temperature is unduly low, and especially as the result of an over-supply of moisture, the grain fails to ripen thoroughly and consequently does not undergo the important changes known as "maturation." The two worst seasons for malting barley in the last decade were 1920 and 1921—the former, one of unusually heavy and persistent rainfall over an extended period, and the latter one of prolonged drought.

Hooker, when dealing with the correlation of the weather and crops, says: "The chief, and very important, requisite for the barley crop appears to be a cool summer. No less than four successive (overlapping) periods show a coefficient greater than $-0{\cdot}5$ with temperature, indicating cool weather from May till the commencement of September, apparently from the time of flowering till harvest; the highest coefficient of all being $-0{\cdot}70$ in the 25th-32nd weeks (say mid-June to mid-August). At this period also there is a large negative

BARLEY (*Continued*)—

coefficient (−0·55) with rain; barley would therefore seem to prefer the somewhat unusual combination of a cool dry summer. There is also a suggestive coefficient indicating dry weather in January and February. This is perhaps in accordance with *a priori* expectations; it is well known that barley seed should be sown in a fine tilth, and this can hardly be secured with a wet, clogged soil. A rainfall above the average does not seem to be a necessity at any time . . ." (R. H. Hooker, "Correlation of the Weather and Crops," *J. Roy. Stat. Soc.*, vol. lxx., Part i., 1907). These deductions, made as the result of a statistical study, are in striking accord with the opinions of those who have had occasion to study the barley crop closely for a succession of years.

At first sight the character of the season appears to present an insuperable obstacle, but some mitigation of weather effects may be obtained by the exercise of a careful choice of variety. Thus, Archer and barleys of that type are capable of producing grain of good malting quality in districts of limited rainfall, whilst relatively early ripening types, such as Goldthorpe, have been found to be capable of successful cultivation in districts subject to a higher rainfall and to a generally lower mean temperature.

Early sowing and the adoption of all the means essential to a vigorous initial growth of the plant are also factors which assist in minimizing weather effects.

Soil—To return to the question of soils suitable to barley, which has been touched on briefly above: when the value of a crop is reviewed on a basis of yield and quality, the conclusion arrived at is that heavy soils are not as a rule conducive to high malting quality, even when the character of the variety is ruled out of the question. Barley is a plant of comparatively rapid growth and development, and, at the same time, essentially a surface feeder. If the weather conditions are such as to permit of the preparation of a fine, dry seed-bed, and the seeding time is succeeded by moderately dry weather, thereby permitting good germination and an easy penetration of the soil by the young rootlets, the quality of the resulting crop, even on heavy soil, may be good. In other words, in this case it is the physical condition of the soil rather than its inherent fertility that largely determines the character of the produce. At the same time, although the intrinsic value of the corn may be good, heavy soils rarely, if ever, produce grain possessing that fine physical appearance so valued by barley buyers.

It may further be said in favour of heavier soils that, provided the crop commences with the advantage of good early growth, the effect of drought is less severe than on lighter soils, which "burn" so badly in prolonged periods of water deficiency. On the other hand, in seasons of heavy rainfall the advantage rests with the light soils. To sum up: in districts of normally heavy rainfall barley is most dependable on light, well-drained soils, whilst in districts of lower rainfall it may on occasion succeed on heavier soils. As a rule, however,

BARLEY (*Continued*)—
the largest acreages are grown on the lighter soils, on which only strict attention to all the conditions insuring the efficient conservation of moisture and thereby an unchecked growth of the barley plants garantees successful crops.

Unlike oats, which can be grown on slightly acid soils, barley demands a neutral or slightly alkaline soil condition.

Position in Crop Rotations—Two of the characters of the barley plant, namely, its relatively rapid growth and development, and its surface rooting, added to its inability to compete successfully with weeds, largely determine its place in the farm rotation. The necessity for a clean and fine seed-bed is imperative, consequently the "break" following roots is the ideal position for the crop.

Barley frequently follows turnips, swedes, mangolds, and sometimes potatoes, but is less good after potatoes than when it succeeds the other roots. When the land is in a high state of fertility and free of weeds it may on occasions succeed a straw crop—usually wheat.

Manuring—When sown after roots the residuum of the manures applied thereto is usually sufficient for the succeeding barley crop. If it follows another corn crop, however, the necessity for the addition of some artificial fertilizers may arise, and these, for a crop with such a relatively short period of growth, must be readily available.

Any mixture of artificial manures then used with this crop must of necessity include some form of readily available nitrogen, but if the grain is intended for malting, a low nitrogen content is fundamentally important, and the application of an excessive quantity of available nitrogen will be reflected, most probably, in the grain in the form of a high total nitrogen content.

The secret of success in manuring barley lies in securing such a balance as, while admitting of an amount of nitrogen requisite for adequate vegetative development, will also, by the addition of minerals, ensure full ripening within the usual period of growth. Consequently, the manure should be a mixture of nitrogen in some readily available form, superphosphate or some other form of readily available phosphatic manure, and potash in the form of kainit or sulphate of potash.

Cases have been recorded in which the application of a nitrogenous manure alone was remunerative, whilst the resulting grain did not suffer in malting value. But the addition of relatively large quantities of available nitrogen in most cases tends to increase the nitrogen in the grain even when, as often happens, this is not brought about by the crop "lodging." Thus, unless there is good reason to act on the assumption that the soil is already sufficiently supplied with minerals in the form of phosphate and potash, the safer practice is to use a mixture composed of the three manures in the proportion of:

1 cwt. sulphate of ammonia,
2-3 cwts. superphosphate,
2-3 cwts. kainit, or 1 cwt. sulphate of potash,

per acre.

If the land as a result of "feeding on," or for other reasons, is known to be heavily supplied with nitrogen, the addition of super-

BARLEY (*Continued*)—

phosphate and kainit, or frequently of one of these only, but more particularly of the superphosphate, will prove beneficial. It may prevent the crop "lodging," which so frequently happens with the luxuriant vegetative development due to excessive supplies of nitrogen, and will, in addition, counteract the tendency to lateness in ripening, another defect arising from the same cause (E. S. Beaven, "Varieties of Barley," *J. Fed. Inst. Brewing*, vol. viii., 1902; H. Hunter, "The Influence of Artificial Manures on the Yield, Chemical Composition, and Malting Qualities of Barley," *University Leeds Bull.*, No. 37, 1904; C. Crowther, *idem.*, No. 75, 1909; A. D. Hall, "An Account of the Rothamsted Experiments," John Murray, 1905; *Dept. Agric. Tech. Instruction, Ireland, Leaflet*, No. 36, 1903, 1904, 1905, 1907; F. Rayns, *J.R.A.S.E.*, vol. lxxxviii., 1927; also, Manuring, the Principles of).

Time of Sowing—There is considerable evidence that crops sown as early in the year as the condition of the soil will permit produce heavier crops and grain of higher quality than those sown later; in addition, the earlier drilled corn appears to produce better standing crops. The reason underlying these observations and actual experiments probably centres round the degree of root development, which is more extensive, relative to the overground vegetative growth, in the cooler period of February and early March than later in the spring.

The more highly elaborated root system secures the plant against the worst effects of drought, and is thus, so far as the quality of the grain is concerned, much more important in seasons of drought than in wet seasons (H. Hunter, "The Barley Crop," E. Benn, London, pp. 51-53, 98-99).

Rate of Seeding—The usual rate of seeding is from 2½ to 3 bushels per acre, but the quantity used is subject to variation with the character of the soil, and to a less extent with that of the time of sowing. On thin, light soils the higher rate of seeding is generally used, for in this case there is no danger of excessive vegetative growth leading to etiolation, and thus to weakness of the straw such as occurs on more fertile soils, and the object is to obtain a "plant" sufficient to cover the land and so avoid too great a loss of moisture.

Early-sown crops may be seeded at a slightly heavier rate to compensate for loss due to inclement weather, whilst those late-sown require additional seeding to make up for the depredations of insect pests such as Wireworm and Leather Jacket, which become more active with the progress of the year.

Varieties characterized by a high tillering capacity, such as **Spratt-Archer,** require a slightly lower rate of seeding than others not well developed in this respect.

But although the quantity of seed and its regular distribution in the rows of the drills is important (see Seed, Spacing of), the greatest recent improvement in the general character of malting barley (apart from the substitution of more prolific varieties possessing at the same time enhanced quality potentialities) has been brought about

BARLEY (*Continued*)—

by the use of pure seed, *i.e.*, seed derived in the case of each variety from a single plant. The advantages secured to the farmer by this procedure have been mentioned previously; they include uniformity in germination and in vegetative development, and subsequently, in ripening. Finally, the grain when marketed exhibits a uniformity in size, and in the degree of ripeness of the grain, both distinctly valuable commercial features, but features that it is impossible to secure in crops produced from seed containing a mixture of varieties.

The additional value of seed that has been kiln-dried is dealt with in Seed, Artificial Drying of.

Harvesting—The methods of harvesting barley are similar to those practised with the other cereals, and do not call for special observation or comment.

The proper time at which to cut the crop is, however, a matter of importance, for large quantities of grain are injured in quality by being cut prematurely. Malting barley must be fully ripe when cut, and this condition is indicated by the complete absence of greenness in the straw, and by the presence of fine reticulations on the skin of the grain. The sequence of changes in the grain as the crop proceeds to full ripeness is from a high to a lower total nitrogen content, and the lapse of even one week at this stage may mean the difference between a barley of high or of inferior malting quality.

The liability to "necking," which was formerly a common feature in most of the broad-eared types as they ripened, is absent in the now predominating broad-eared variety, Plumage-Archer, whilst Spratt-Archer, like its parent Archer, may be allowed to stand for a considerable period after reaching full ripeness without the ears becoming detached from the straw. Thus, the necessity of cutting the crop before it has reached full ripeness in order to avoid loss of grain no longer provides a legitimate reason for premature harvesting.

For Diseases and Insect Pests see articles immediately following Wheat; for Composition, Feeding Value, and Manurial Value see Feeding Stuffs; and Poultry, Nutrition. Other articles to which reference should be made are Grain, Commercial Standards of; and Seed, Transmission of Plant Diseases by. H. H.

BAROMETER—An instrument for measuring atmospheric pressure, *i.e.*, the pressure exerted on each unit of area of the surface of the earth by the superincumbent weight of the air above it. If a tube a yard long be sealed at one end and filled to the brim with mercury, on placing the tube vertical with the closed end uppermost and the open end dipped below the surface of mercury in a trough, the mercury column will leave the upper, closed end, and come to rest in such a way that the column of mercury in the tube will stand about 30 ins. above the mercury surface in the trough, the space above the mercury column remaining vacuous except for the pressure of mercury vapour. To produce a similar phenomenon with water at 0° C. would necessitate a tube more than 34 ft. long. The mercury column is supported in

BAROMETER (*Continued*)—
the tube by the pressure of the air on the surface of the mercury in the trough; if this pressure becomes less, the mercury column falls a little, and if it becomes greater it raises the height of this column, and thus indicates what the atmospheric pressure is at the moment. The instrument is known as a simple barometer.

For practical use the bottom of the trough is replaced by a wash-leather bag, and by means of a screw impinging on this, the mercury surface in the bag can be brought to a definite mark before the height is read by a vernier scale fixed on a brass tube surrounding the glass one. Such an instrument is known as a Fortin's barometer, and all standard instruments are of this pattern.

For use at sea a modification of this known as the Kew pattern is made, in which swinging of the mercury level is almost damped out by a long constriction in the middle of the tube, and the scale engraved on the glass is made smaller to compensate the changes of level in the cistern, so that it is unnecessary to bring the mercury surface to any fiduciary mark.

Barometer readings have to be corrected, if extreme accuracy is desired, for the different expansions of the mercury and glass, and of the glass and brass tubes; also for height above sea-level, since at an elevated point the amount of air above one is less and, therefore, presses less upon the mercury surface. A correction has also to be applied for latitude, since the gravitational attraction is less, and the centrifugal force greater, at the equator than at the poles. Finally, corrections have to be made for capillarity and angle of contact of the mercury with the glass.

In an aneroid barometer a different principle is employed. A flat vacuum box, or a series of them, is screwed securely to a base plate, while the top is connected to a spring which pulls on the box, so that variation of air pressure moves the lid very slightly; from this a lever and chain mechanism to the dial hand serves to magnify the very slight movement of the lid enormously. The best instruments are compensated for temperature variation by bi-metallic compensation or "invar" parts; but in any case are quite unreliable as to the absolute measurement of pressure unless frequently compared with standard instruments, owing to what is called "creep" due to unavoidable faults in elasticity of the materials of which they are constructed, wear, etc. (See Meteorology.)

BASIC SLAG—See Fertilizers.

BEANS—Beans have been cultivated as a crop from very remote times. They were well known in Ancient Egypt, and there is a reference to them in 2 Samuel xvii. 28, where they are mentioned as being given by Barzillai the Gileadite, and others, to the followers of David.

Nothing is known with certainty of the origin of beans, although De Candolle expressed the view that they were introduced into Europe by the Aryans. He concluded that they grew wild in two centres:

(1) South of the Caspian.
(2) In North Africa.

BEANS (*Continued*)—

It is supposed that the Romans introduced beans into Great Britain, and that the generic name, *Faba vulgaris,* was derived from the famous Roman family of Fabius.

Beans were grown under the old feudal system, and there can be little doubt that beans and peas proved especially valuable in enriching the land for cereals before the introduction of clover. No doubt, also, the grain was of particular value both to man and beast, owing to its richness in protein, at a time when the sources of that substance were not so varied or so easily obtained as at present. (See Feeding Stuffs.)

Symbiotic Organisms in Roots—Beans belong to the Natural Order Leguminosæ, and, as in the case of other members of that order, numerous nodules or swellings are found upon their roots. These nodules are caused by micro-organisms which live in symbiosis with the plant, and enable it to utilize the free nitrogen of the air, which, in the absence of the organism, it is unable to do. From time to time this organism has been cultivated artificially, and the seed inoculated, with a view to benefiting growth.

Struthers (*West of Scot. Agric. Coll. Rept.*, 1905) states that no difference in resulting crop was observed from inoculation of the seed with Hiltner's cultures.

Wright (*West of Scot. Agric. Coll. Bull.*, No. 42, 1907) was of the opinion that the practice of inoculating the seed seemed likely to be attended with beneficial and profitable results on the majority of bean soils, although on some soils, like that of the College station, no good effect was obtained. At the present time (1930) no beneficial method of inoculating beans is known to the writer, and it is probable that most, if not all, soils in bean-growing districts of Great Britain contain a sufficient supply of the organism requisite for the production of nodules.

As a result of their ability to assimilate the free nitrogen of the air, beans and other leguminous crops actually enrich the soil in that plant food. Hence the practice of growing them in rotation with cereals has arisen, the cereal which follows greatly benefiting by the nitrogen accumulated in those portions of the leguminous crop which are ploughed in. This is undoubtedly one of the greatest advantages secured by a rotation of crops. (See Rotations.)

Botanical—A number of plants are included under the name "beans." Linnæus grouped the common bean with the vetches in the genus *Vicia.*

Field beans, however, differ from vetches in the character of the stems, which are erect and capable of standing without support, and in regard to the leaves, which are large and fleshy, whilst the tendril usually present in vetches is very rudimentary in the bean. Hence it is usual to place them in a separate genus, *Faba,* the field bean being known as *Faba vulgaris* (Moench).

Garden beans include the broad bean, which is of similar habit to the field bean, except that the stem is rather stouter, the pods broader

BEANS (*Continued*)—

and longer, and the seed larger and flatter. For culinary purposes, the seeds of the broad bean are used in an unripe state, whilst the kidney bean (*Phaseolus vulgaris*) and scarlet runners (*Phaseolus multiflorus*) are grown for the pods, which, with their contents, are eaten in the green state. French beans are dwarf in habit, but scarlet runners have long, twining stems which require support.

In Great Britain the only bean which is at present grown to any extent as an agricultural, as distinct from a market-garden, crop is the field bean. The field bean has a four-sided hollow stem, which grows to a height varying from 2 to 5 or even 6 ft. When ripe, the whole plant turns a very dark, almost black colour. The seeds of the field bean vary in size, shape, and colour according to the variety.

Varieties—As previously noted, *Winter beans* are by far the most important kind of bean in the English bean-growing districts, and frequent attempts have been made by seedsmen and others to introduce improved strains. Some of these have been tested by the writer over a period of years on field plots in Suffolk. It may be noted that, owing to irregularities of plant which usually occur amongst beans, the difficulties attending quantitative trials are perhaps even greater than those met with in cereals.

Plots of somewhat less than an acre in extent, and arranged in triplicate, led to the conclusion that a selection of winter beans made by Dr. H. Hunter of Cambridge, known by him as Sudbourne No. 9, was superior to the local strain of winter beans to the extent of something like 8 stones per acre, although in appearance there is little to distinguish the two strains. A large-grained variety of beans put on the market by a seedsman was included in the test, and was apparently inferior to the local strain in cropping power.

Spring beans also are grown on a fairly large scale in the bean-growing counties; in addition they are grown occasionally in mixture with peas, making the crop known as "blendings." Spring beans are generally inferior to winter beans in tillering capacity; they also usually flower two or three weeks later, for which reason they are more susceptible to aphis attack.

Tick beans, a spring form grown to a considerable extent in the eastern counties, are usually much smaller than other spring sorts, from which they also differ in being approximately spherical and free of indications of lateral depressions. A very small bean of the *Tick type* is known as the *Pigeon bean*.

The *Heligoland bean* is another small spherical type; the seeds are chocolate-coloured; the *Mazagan bean* is a large flat-seeded sort.

In addition to the beans mentioned above, which are usually buff or greenish-buff coloured, there are other sorts which are red and purplish coloured. Many strains of the latter have been tried in various places from time to time, but they do not appear to possess any feature sufficiently valuable to induce their extended cultivation.

Viewed generally, the differentiation of the bean into definite varieties is a matter of considerable difficulty. There are clear in-

BEANS (*Continued*)—

dications of a division into sorts which are capable of withstanding the conditions of winters usually met with in this country, and others are quite as definitely unable to do so. But the vegetative characters of strains in each of these main groups offer little ground for further differentiation, which must consequently be made on the character of the grain. Here, in addition to a wide normal fluctuation, the effect of cross-fertilization, due principally to bees, is encountered (see Plates I and II, Figs. 1-4). Viewed in fairly large bulks it is possible to differentiate between, say, the ordinary *Winter bean* and the *Tick bean*, for both shape and size will here assist, but unfortunately it is impossible to support an opinion formed on this basis by a subsidiary character such as the colour of the hilum, for this varies in a manner to which it has not been possible up to the present to apply a consistent interpretation.

Suitable Climatic Conditions—The climate of southern and eastern England is, as a rule, suitable for winter beans, and only occasionally, perhaps on an average of once in ten years, are they severely damaged by frost. Most harm is done by a frost occurring when there is little or no snow on the ground. If on examination in March the stems are found to be frost damaged, it is advisable to drill in some "filling up' crop, such as peas, at once, as although the beans may not be dead, they will almost certainly fail to produce a full crop. An early variety of peas, such as the "Dun," drilled in March or early April, will ripen about the same time as winter beans. In the north of England and in Scotland the climate is usually too severe for winter beans, and spring beans are grown.

Winter beans will give satisfactory crops in very varying types of seasons; in fact, provided they survive the winter satisfactorily, they are more reliable than spring beans, and are preferred in those districts which as a rule have a suitable winter.

Beans thrive best with a fair rainfall during summer, and as they usually come into flower in May, a good growing time in that month is a great advantage. Extremely hot weather is not an advantage, and in some seasons leads to an attack of the black aphis.

Spring beans thrive best in a fairly showery May and June; very hot weather in late June or July frequently favours attack by the black aphis, to which they are much more subject than winter beans; occasionally the attack of black fly may be so severe as to ruin the whole crop. When it is evident that there is little chance of the crop being satisfactory owing to the attack, probably the best plan is to cut it and make it into silage, and plough up the land immediately after the crop is removed.

Soil—Beans are essentially a heavy land crop; they will, however, give excellent yields on medium loams in seasons of average rainfall, whilst in wet seasons comparatively light soils produce good crops. The crop will not grow satisfactorily, however, in the absence of a sufficient and preferably an abundant supply of lime. This is well exemplified in fields containing large patches deficient in lime,

PLATE I

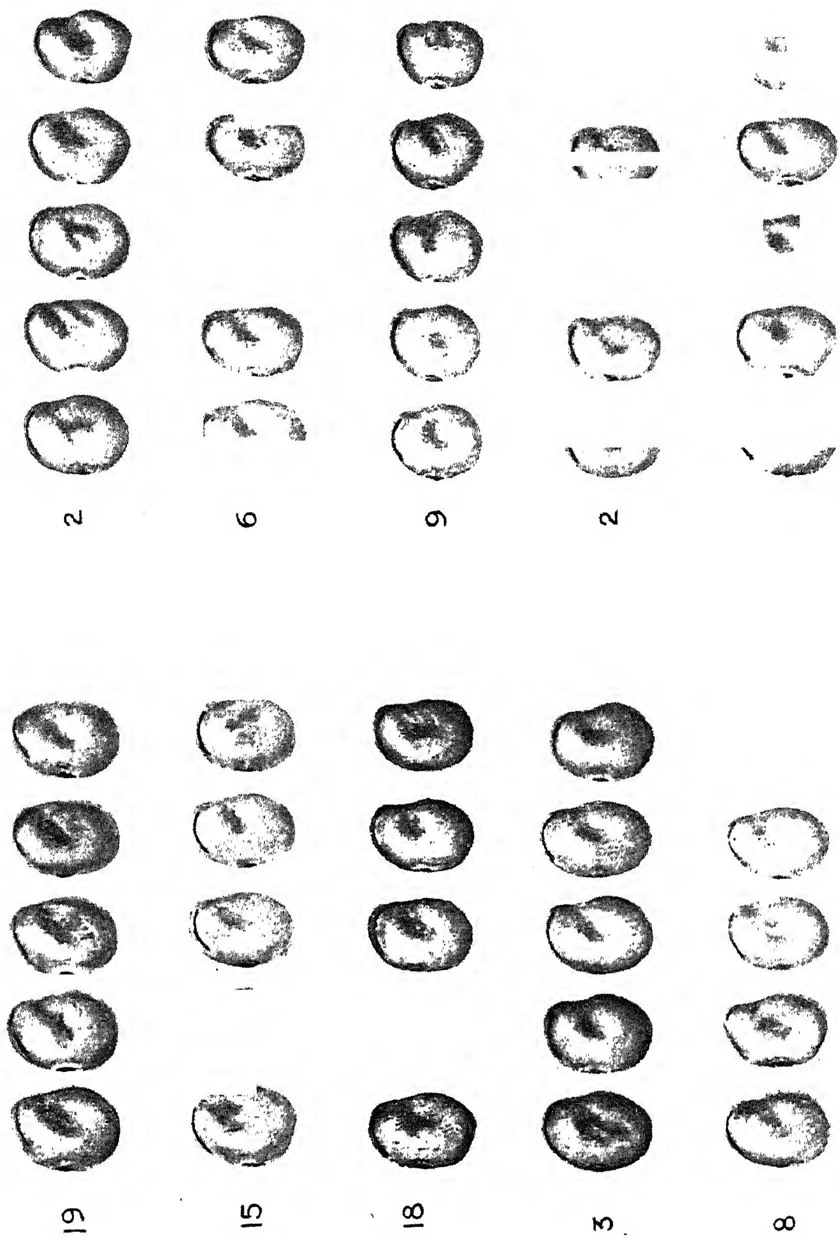
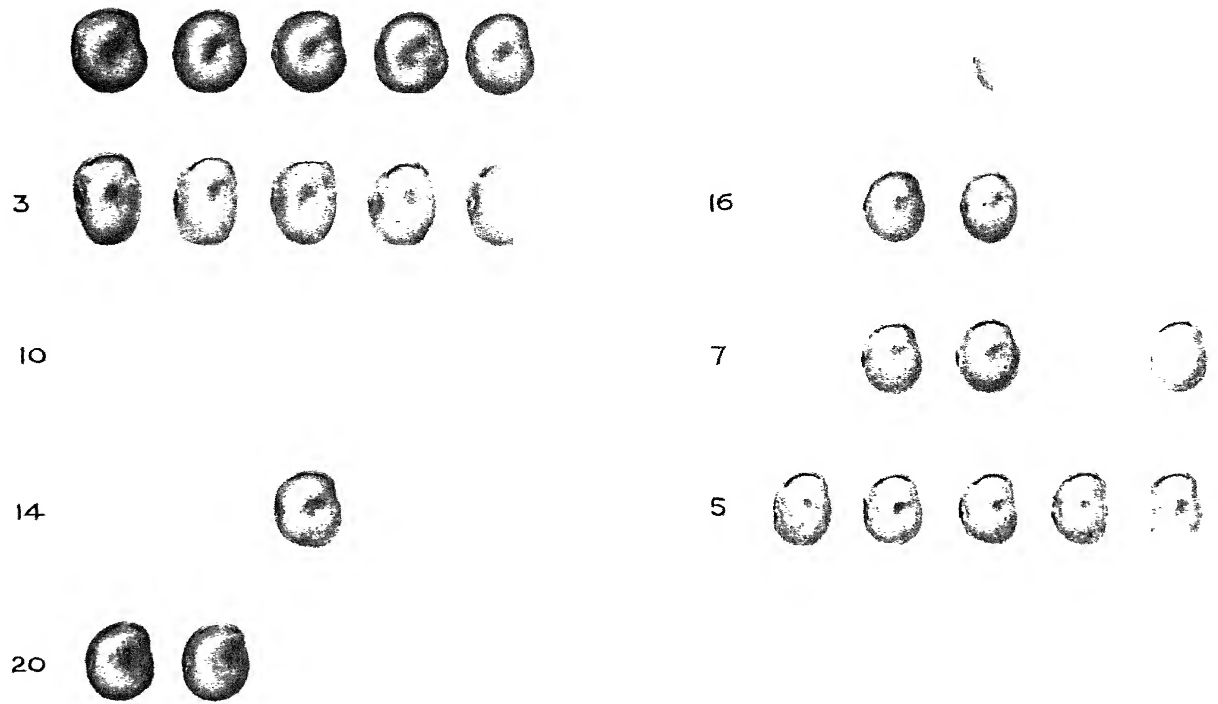


PLATE II



HOWING TWENTY REPRESENTATIVE SA S (EACH S PLE CONSISTING OF THE PRODUCE OF WENTY BE. OBTAINED OM ONE PLANT.

arranged an a 'age seed-weight of ye as well as in size.

BEANS (*Continued*)—

for while the beans will usually fail in these patches, they produce a satisfactory crop on the portions of the field containing sufficient lime.

The Chalky Boulder Clay, which occurs in a wide ring round the Wash, in the counties of Leicester, Northamptonshire, Bedfordshire, Essex, Suffolk, and Norfolk, weathers down to what, in many cases, is almost an ideal soil for beans. The chalk nodules contained in this soil, together with its heavy nature, produce an ideal combination for beans.

Although beans like a heavy soil, it is essential that it should be well drained. A waterlogged condition is fatal to satisfactory growth, and on badly drained land, after a wet winter, large patches of the crop are frequently ruined.

Position in Rotation—Beans are, as a rule, grown after a cereal, and are usually followed by a cereal, frequently wheat. In the Norfolk four-course rotation of (1) roots, (2) barley, (3) leguminous crop, (4) wheat, the leguminous crop may be clover, beans, or peas. As a rule the clover and the beans or peas alternate, so that the beans and peas occur once in eight years. There is no doubt that this arrangement, whereby the beans are not grown on the same land too often, is a sound one, for it reduces the danger of disease. (See Rotations.)

Attempts made at Rothamsted some years ago to grow beans on the same land year after year resulted in failure. The underlying reasons of this are not fully understood, but it appears likely that attacks of fungus pests, such as *Sclerotium* or Stem Rot, are partly responsible. It is, however, quite possible to grow beans on the same land two years in succession, and self-sown crops of beans are sometimes successful.

A rotation practised on heavy land years ago was the three-field course—wheat, beans, and fallow.

In the Essex six-course rotation, beans come between two crops of wheat as follows: (1) wheat, (2) winter beans, (3) wheat, (4) fallow, (5) oats, (6) clover. This is a rotation suitable for heavy land where roots are difficult to grow.

In the East Lothian six-course rotation we have: (1) wheat, (2) seeds hay, (3) oats, (4) spring beans, (5) wheat, (6) roots or fallow. Whilst it is usual to grow beans after cereals, they may be grown quite well after other crops. During the war it was found that they could be grown satisfactorily after grass land newly broken up. The grass land was ploughed up in late September or early October and winter beans were drilled immediately, or the grass was ploughed up during the winter and spring beans were drilled in February or March.

Although Wireworm will attack beans, the risk of their doing serious injury is not so great as in the case of a cereal crop. Hence, as Wireworm attack is one of the great dangers of newly broken-up grass land, beans may be regarded as a suitable crop to grow on such land.

In Scotland a mixture of beans and oats, known as "mashlum,"

BEANS (*Continued*)—

is often grown after temporary pasture. This practice is sound, in that a mixed crop is less likely to failure than a single crop. In a case such as above, if the Wireworm or Leather-Jackets, which are so often present in broken-up pasture, attacked the oats, the beans might escape. Quite a common plan, in order to secure ripening of beans and oats at the same time, is to sow the beans first, following with the oats just before the beans come up. The varieties of beans sown in mashlum are the Carse and the Kilbride, and a late ripening variety of oats is usually chosen.

In certain districts in England a mixture of spring beans and a late ripening variety of peas is sometimes grown. At the Saxmundham Experimental Station, a mixture of 2 bushels of spring beans and ¾ bushel of maple peas was found to give excellent results on land recently broken up from pasture which was infested with wireworms. The crop grown in the above proportions formed a dense and tangled mass, but was cut with a binder without undue difficulty. Owing to the dense shade it produces, such a crop is excellent for keeping down weeds.

Manuring—The manuring of beans has not received so much attention from scientific workers in this country as those of many other crops. At Rothamsted an attempt was made to grow them continuously on the same land, with various manurial treatments. These experiments gave very interesting results, but there were frequent complete failures of crops. Sir J. H. Gilbert, lecturing on these experiments at Cirencester in 1889 (see *Agricultural Students' Gazette*, New Series, vol. iv., parts 5 and 6), stated that there was a considerable increase of crop from mineral manures containing potash, but the further addition of nitrogenous manures gave comparatively little further increase.

Aitken (*Trans. High. and Agric. Soc.*, 1885 and 1886) concluded that potash has the greatest effect in increasing the bean crop. After that came lime and phosphoric acid; soluble phosphates were better than insoluble. Nitrogenous fertilizers—sulphate of ammonia, nitrate of soda, dried blood and horn dust were much less important, and were apt to retard the crop. Farmyard manure was not included in these experiments. Wright (*West of Scot. Agric. Coll. Bull.*, No. 42, 1907) states that as the result of two years' experiments at a number of centres in the West of Scotland, the most profitable returns were obtained from an application of 6 cwts. superphosphate and 2 cwts. sulphate of potash per acre, with inoculated seed; nitrate of soda added to these manures appeared to be of doubtful advantage.

Experiments on manuring beans conducted at Cockle Park, Northumberland ("Cockle Park Guide," 1913) showed that basic slag gave better results than superphosphate; muriate of potash added to slag increased the crop by 6 bushels of grain per acre when farmyard manure was used, and by 7 bushels when it was not used. Lime mud, added to superphosphate, considerably increased the crop.

At Saxmundham Experimental Station, Suffolk, rotation experi-

BEANS (*Continued*)—

ments were started on poor, heavy land in 1899, and are still in progress (1930). In these experiments, beans and clover have been grown as the leguminous crop in the Norfolk four-course rotation of roots, barley, leguminous crop, and wheat. As the experimental field is divided into four sections treated as separate fields, each of which is cropped every year with one of the crops of the rotation, results are available from either beans or red clover every year. (See "The Manuring of Beans and Red Clover," *J.R.A.S.E.*, vol. lxxxiii.; also A. W. Oldershaw and John Porter, "British Farm Crops," E. Benn and Co., London.) For the period in question, beans have been grown at Saxmundham during twenty seasons. Farmyard manure has been found to give highly beneficial results; in fact, the conclusion has been reached that they are one of the most suitable crops to which to apply that manure. Over a period of ten years, every ton of farmyard manure applied has given an increased grain yield valued at 12s., assuming the pre-war price of 4s. per bushel. In addition, the residual effects of the application have been considerable. Phosphates and potash also produced very striking results, but the application of nitrate of soda alone, or in conjunction with phosphates and potash, has produced very little effect.

The beneficial effect of farmyard manure is somewhat difficult to explain. In view of the small results of nitrogen in a chemical form, it seems unlikely that it is the nitrogenous ingredients of the farmyard manure which are chiefly responsible for the improvement. The bean obtains much of its nitrogen from the air, and experience at Saxmundham proves that, in the absence of farmyard manure and of artificial nitrogenous manures, it can make very good growth if phosphates and potash are applied. Nevertheless, the nitrogen in the farmyard manure may assist the beans in their early growth. No doubt the potash and phosphates also are very beneficial, whilst it is by no means improbable that the micro-organisms in the manure may be a help. In addition, the manure being ploughed under in autumn assists in keeping the soil open during the winter, which on heavy land may be a considerable benefit.

In the following summer it helps to retain moisture, which in a dry season will be a great advantage to the beans.

As a result of the experiments at Saxmundham and elsewhere, it appears that on heavy land the following manurial treatment is suitable in most cases:

(1) A dressing of 10 tons of farmyard manure and 3 to 4 cwts. 30 per cent. superphosphate, or 4 to 5 cwts. of 30 per cent. basic slag, per acre.

(2) If farmyard manure is not available, a dressing such as the following may be used with confidence:

(*a*) Four cwts. of 30 per cent. superphosphate (or its equivalent of other qualities) per acre.
One cwt. muriate of potash (or its equivalent of other potash manure) per acre.

BEANS (*Continued*)—

Or, (*b*) Seven cwts. of 30 per cent. basic slag (or its equivalent of other qualities) per acre.

One cwt. of muriate of potash (or its equivalent of other potash manures) per acre.

Kainit is not a very suitable form of potash to use on heavy land, as it is apt to injure the tilth.

Whether the soil is heavy or light, it is essential that a sufficient supply of lime should be present. It is not improbable that the general idea that beans are unsuitable for the lighter types of soils is due partly to the fact that such soils are often deficient in lime.

On light loams containing an abundance of lime, very good crops of beans are often obtained in a wet summer; in fact, in such a season beans may give better yields on the lighter types of soil than on heavy land.

Sowing—There are many ways of sowing beans, but in those districts where the biggest area of beans is grown, the usual methods are drilling with a cup drill, and ploughing in, every second or third furrow. When beans are to be drilled with a cup drill, the land is ploughed and worked down as for cereals. The usual seeding is 2½ bushels (11 to 12 stones) per acre.

Probably the best time to drill beans in the autumn is during the first three weeks in October. If a mild period follows too early sowing, the crop makes too much growth, and may then suffer unduly from frost damage. On the other hand, late-sown beans seldom make really good crops. When beans are ploughed in, a little one-row drill is used, attached to the plough. If the land has been scarified and a surface mould made, the conditions are better for ploughed-in beans than if a tough and unkindly surface is ploughed under. A furrow of about 4 ins. depth is usually taken. The advantage of this method is that once the beans are in, there is no fear of heavy rain making drilling difficult; further, they are out of reach of vermin.

Spring beans are usually drilled with the cup drill, and should be the first corn to be drilled in spring. Whilst February is a favourable time in the south, east, and midlands of England, a later date is suitable farther north.

Sometimes, in the north of England and in Scotland, beans are sown in ridges, baulks, or drills, 24 to 27 ins. wide. In this case the ridges are opened, farmyard manure applied, and the beans sown by hand and covered by splitting the ridges, which are then rolled to consolidate them.

Treatment during Growth—Beans, if well horse-hoed, may be made into a cleaning crop; on the other hand, if neglected, there are few crops which tend to foul the land more; especially is this the case with poor and thin crops.

As soon as the land is dry enough in March, beans are harrowed to break the surface crust, level the ground, and kill seedling weeds, and shortly afterwards the first horse-hoeing is given. A horse-hoe, in the

BEANS (*Continued*)—

hands of skilled workmen, is one of the cheapest and best ways of dealing with weeds.

Harvesting—In the southern half of England, winter beans are usually ripe in a normal harvest early in August, and sometimes even earlier.

It is important to cut beans before they are absolutely dead ripe, or serious loss may occur owing to shelling of the grain, especially when the ground is very dry and hard. A safe rule to follow is to cut when the hilum, eye, or point of attachment of the grain to the pod, is black. The straw at this time may not be quite black and ripe, but will ripen in the shock. Beans are usually cut with the binder. Occasionally they may be podded so low that it will pay to cut them by hand with a "badging" hook, or even to pull them by hand. The shocks or stooks should not be too large. Although beans take very little damage from showers, they will mould after a heavy rain, consequently, under such conditions it may be necessary to move the shocks to allow the better penetration of air.

Thrashing and Yield—Beans are thrashed with the ordinary thrashing machine. Very often a stack of beans is left until March or April, or even later, before thrashing, as old beans are found to be more valuable for food for stock than new ones.

The yield of beans is very variable, depending to a great extent upon the season. In some seasons their yield is seriously reduced by frost damage (in the case of winter beans), attack by Weevil in May, or Black Aphis in June and July. Occasionally the crop is damaged by the Stem-rot fungus in early spring, and by the Chocolate Spot disease, which attacks the leaves later in the season. Generally, 36 bushels of grain and 25 cwts. of straw is an average crop, but 50 bushels or more of grain is not uncommon in a favourable season.

OTHER BEANS OF IMPORTANCE IN BRITISH AGRICULTURE—
Soya Bean (*Glycine soja,* syn.: *G. hispida*)—This bean is related to the scarlet runner and the haricot bean. There are many varieties, but in general the plant may be described as an annual, stems sub-erect or climbing, 1½ to 4 ft. high. There are three or four nearly spherical seeds in each pod; the colour of the seeds is black, brown, yellow, green, and mottled, according to variety. It is grown chiefly in Manchuria, northern China, Japan, and America, but recently attempts have been made to obtain varieties suitable for cultivation in the British Isles.

Attempts to acclimatize the Manchurian soya bean were commenced at the Royal Botanic Society's Gardens, Kew, in 1914. In the Quarterly Summary published by that Society in April, 1929, North states that these experiments have proved conclusively that there are certain varieties of soya which can be depended upon to ripen seed and give a crop early enough to be harvested in September.

It appears that a hybrid received from Professor W. Southworth, of Manitoba Agricultural College, Canada, in 1922, in seven years' trials

BEANS (*Continued*)—

has proved to be not only the most reliable cropper, but the earliest of any of the sixty varieties of soya tested. It is inadvisable, however, to attempt cultivation on a large scale before a preliminary smaller test.

Soya bean plants require ample space between the rows, 27 to 30 ins. being suitable, and the land must be kept free of weeds. The seeds are sown 2 ins. deep and 3 to 4 ins. apart at the beginning of May. The crop is harvested when the pods turn yellow, generally in September. A light loam is the most suitable type of soil. Inoculation of the soil with soil containing the nodule organism has, in some cases, given beneficial results in this country.

The cultivation of the soya bean must be regarded as still very much in the experimental stage, and it is by no means certain that any of the strains tried are suitable for cultivation over large areas under British conditions. It is to be hoped, however, that the efforts now being made to acclimatize this most valuable plant will be successful.

Soya beans are imported into this country in large quantities. The oil is usually expressed, and the residue forms a very valuable cattle feeding cake or meal, especially useful as a source of protein.

Java and **Rangoon** beans, varieties of *Phaseolus lunatus*, which are sometimes imported, should be used with considerable caution. They have been found to contain a cyanogenetic glucoside, which, under the influence of an enzyme present in the seed, produces prussic acid when macerated with water, which may have fatal effects upon the animals consuming the beans.

As a measure of safety, Voelcker ("Standard Cyclopedia of Modern Agriculture") advises the farmer to refrain from purchasing bean meal altogether. In this way he will avoid the possible presence of harmful ingredients, and also of an undue amount of husk.

Locust Beans (*Ceratonia siliqua*)—The thick pods of this bean have a sweet taste and pleasant smell, and are valuable as a condimental food, being perhaps most commonly used, in mixture with other materials, in "lamb foods." The locust bean grows in districts bordering the Mediterranean. The pods are shaken off the tree whilst still unripe, and dried in the sun. (For composition and nutritive value of grain and straw of beans see Feeding Stuffs.) A. W. O.

INSECT PESTS OF PULSE CROPS—The Bean Aphis (*Aphis rumicis*), also popularly known as "black fly," "black army," or "blight," is very common on beans and in some seasons causes serious losses. The black masses of these insects, found usually in dense colonies on the tips of the plants, on the lower surfaces of the leaves, and on the pods, are well known. Davidson (*J. Min. Agric.*, xxii., 1925) has worked out the life history of this pest.

In addition to the broad bean this pest is commonly found on other hosts. Of the weeds, docks (*Rumex*), poppies (*Papaver*), fat hen (*Chenopodium album*), shepherd's-purse (*Capsella Bursa-pastoris*), and various kinds of thistles (*Cnicus*) are commonly infested; it is found also on the following cultivated plants: beet and mangolds (especially when

BEANS (*Continued*)—

grown for seed), rhubarb, spinach, turnips, nasturtiums, dahlias, and on French and runner beans.

In late summer the aphis migrates to the spindle tree (*Euonymus europæus*), where eggs are laid. In the spring these eggs hatch and give rise to females which produce living young, and soon winged forms appear which fly off to beans and other hosts. In sheltered situations the egg stage may be omitted, and the aphis may live on its summer host and also on the spindle tree throughout the year.

The intensity of the attack is largely influenced by weather conditions, moderately high temperatures being especially favourable for rapid increase in numbers. This pest (like other aphides) is partially controlled by ichneumon parasites which lay eggs inside the bodies of the aphides.

Control—Owing to their faculty of increasing rapidly it is difficult to deal with an infestation on a field scale. Winter beans suffer less than those sown in the spring, and early sown spring beans usually suffer less than those sown later. Good cultivation and manuring will produce strong plants likely to suffer less from attacks and to recover more rapidly when the aphides are checked by weather conditions or parasites. Some growers subsoil for beans to reduce the damage caused by this pest.

In the early stages of attack the pest may be very localized; at Cambridge the headlands of a bean field where the attack started were cut, and this materially reduced the damage to the rest of the field.

Weed hosts should be kept in check as much as possible. The destruction of *Euonymus* has been advocated in parts of France as a method of controlling the aphides on sugar-beet. Davidson says: "This, however, would not, I believe, have the desired effect in England. Although the spindle tree has been proved to be a winter host, the insect can winter in other ways."

In the garden the pest is easier to control. When an attack starts on broad beans the top 6 ins. of the plant should be removed and destroyed, for this practice usually markedly reduces the progress of the infestation.

Spraying with a satisfactory contact insecticide is also effective in dealing with this pest.

Pea and Bean Weevils (*Sitona* spp.)—These weevils (of which the chief culprit is *Sitona lineatus*) attack peas and other leguminous crops in a very characteristic manner by eating small semicircular patches out of the edges of the leaves. They are small, brownish-coloured weevils, with a very short rostrum, and measure about $\frac{3}{16}$ in. in length. They are difficult to find, unless the plant is approached carefully, as they readily fall to the ground and remain motionless.

In addition to the damage caused by the weevils feeding on the leaves, the small, creamy, legless larvæ feed on the roots and especially on the nodules, thus injuring the root system. These larvæ hatch from eggs laid in the soil around leguminous plants by weevils which

BEANS (*Continued*)—

have lived there through the winter. There is only one generation every year.

The greatest damage is done in the early stage of the plant's growth. In a normal season the young plants are able to produce leaf tissue more rapidly than the weevils can eat it, but, in seasons in which the plants are badly checked for some time, the weevils, when they are sufficiently numerous, eat the leaves as rapidly as, or most rapidly than, they are produced.

Control—A fine tilth helps to check the damage done by these pests, as they usually shelter under clods. Good cultivation and manuring will help the plants through the early stages in which the worst of the damage is done.

Covering the plants with soot or even dust is useful in keeping this weevil in check, and where possible these should be applied after a heavy dew or rain. Many hibernating weevils will be destroyed by burning rubbish which has accumulated.

The Pea and Bean Seed Beetles (*Bruchus pisi* and *Bruchus rufimanus*). These pests are very common both in home-grown and imported peas and beans. *B. pisi* attacks peas and *B. rufimanus* is found chiefly in beans. The beetles live through the winter either in the seeds or in sheltered places. They lay eggs on the young pods in the flowering stage, and the legless, wrinkled larvæ which hatch out make their way into the seeds. They feed on the seeds but usually do not injure the embryo. They also change into the pupal and beetle stages in the seed. The seeds in which the beetles are present have a small round pit in the skin of rather different colour than the rest; no holes are made until the beetles escape.

Control—Seeds containing live beetles should not be sown, but the beetles are readily killed by fumigating either with carbon bisulphide or with carbon tetrachloride. Details of treatment can be found in the Ministry of Agriculture's Leaflet No. 150.

The Pea Moth (*Laspercysia nigricana*)—This moth is responsible for heavy losses in districts where peas are grown extensively; it is particularly troublesome where peas are grown for bottling or packeting.

Miles (*Bull. Chamber Hort.*, vol. iii., part 1, March, 1926) gives a detailed account of its life history.

The moths are present from early June to mid-August, and lay eggs chiefly on the sepals at flowering time. The whitish caterpillars which soon hatch from these bore their way through the wall of the pod and feed on the developing peas. When fully fed they eat their way out of the pods and enter the soil, where they remain usually in the top 2 ins. Here they construct a silken cocoon in which they live till spring; they then pupate and in June or later give rise to moths.

Control—No satisfactory control of this pest is known. In 1925 Miles carried out some experiments in Lincolnshire. He obtained very little control when the peas were picked at the stage for marketing

BEANS (*Continued*)—

green. When the peas were ripe, derris extract (applied when the last 25 per cent. of the flowers were open) reduced the number of damaged peas by nearly 50 per cent.; a very similar result was obtained with soft soap and nicotine applied at the same time or when the first 25 per cent. of the blossoms were open. Dusting with proprietary dust at the later time gave practically no control. F. R. P.

BEEF PRODUCTION (food requirements for)—See Foods and Feeding.

BEETROOT—See Market Gardening.

BENCH MARKS—A broad arrow, apex upward, surmounted by a horizontal bar; they are placed on stones and other fixed objects to mark the sites of the "benches" for the levelling staffs used in government surveys. The bench was often a piece of angle iron let into the stone to give a solid foundation on which to rest the staff. Hence, where levels are given at bench marks they refer to the "bench" or horizontal bar. (See Ordnance Survey.)

BIRD'S-FOOT TREFOIL—See Legumes, Breeding of Herbage.

BISCUIT MEAL—For composition and value when fed to poultry see Poultry, Nutrition.

BLACKBERRY—See Soft Fruits, under Fruit.

BLINDNESS (in barley)—See Diseases of Cereals, under Wheat.

BLOOD, DRIED—See Fertilizers. For composition and feeding value see Feeding Stuffs; also Poultry, Nutrition.

BONE MANURES—See Fertilizers.

BONES, MARROW—The long bones of the limbs of animals. Valuable fats used for making fine soaps and pomades are obtained from the marrow fat. To obtain this the ends of the bones are sawn off and the shafts soaked for three days in weak brine, after which they are simmered for six hours in hot water, when the fat can be skimmed off the surface. The boiled-out bones yield buttons, gelatine, poultry and dog foods.

BORAX—Sodium diborate, $Na_2B_4O_7,10H_2O$, a crystalline salt soluble in water, found in West America, Tunis, and Tibet. Easily fuses with loss of the ten molecules of water of crystallization, leaving a glassy mass which is an excellent solvent for metallic oxides, the solutions having usually characteristic colours. It is on this property of dissolving oxides that its usefulness as a flux in welding depends.

BORIC ACID (Boracic Acid) H_3BO_3, is present in all fruits. It has a faintly antiseptic action and, until the practice was forbidden in 1927, was largely used in small quantities for preserving fresh foods, such as milk and butter. Its antiseptic properties are so weak that it is practically useless for disinfecting or dressing septic wounds; its surgical and veterinary value is rather in preventing further infection of parts which have already been rendered non-septic by other more thorough means. The medicaments used for this purpose often have

BORIC ACID (*Continued*)—

a more or less destructive action on the tissues if kept too long in contact with them, and it is here that boric acid finds its great use.

BOT AND WARBLE FLIES—The larvæ or maggots of the flies (*Diptera*) belonging to the family *Œstridæ* are parasitic within the bodies of vertebrata. There are several species which are thus endoparasitic in stock and are a source of considerable loss to farmers. These are the Bot Flies, the Warble Flies, and the Sheep Nostril Fly, and it is the purpose of this article to describe these insects, their life history, and the measures for their control, so far as these are known. The *Œstridæ* are all parasitic in mammals, and as a rule each species parasitizes a single species of host and each genus or group of allied species attacks allied hosts. The most important of these parasitic flies are the so-called *Warble Flies* or cattle grubs, and these will be dealt with first.

There are two species in Great Britain, *Hypoderma lineatum* de Villers and *H. bovis* de Geer, and the larvæ of both inhabit the bodies of cattle.

The Ox Warble fly, Heel fly (*Hypoderma lineatum* De Villers).

Description—The adult fly is a large hairy insect rather more than ½ in. in length, somewhat resembling a humble bee, but, of course, with only one pair of wings. The general colour is black with bands of yellowish and orange hair, the thorax is covered with black and white hairs and there are four distinct longitudinal lines, the abdomen is covered with blackish hair and the terminal segments are orange red. The egg is dull yellowish white with a smooth shining surface, slightly longer at the base than in the middle. Each egg is attached to the hair by an oval clasp. The larva or maggot, when full grown, measures about 1 in. in length and has a rugged surface with a spiny armature. The puparium or chrysalis is similar in shape to the larva, but is smaller and almost black in colour.

Life History—The adult flies make their appearance in May and June, and occur in greatest numbers about the middle of July. The eggs are deposited mostly on the heels of standing cattle, but are occasionally also laid on the sides and shoulders; they are attached to the hair by means of a clamp with the addition of some adhesive substance, usually in regular rows of about twelve. The young larva emerges from the egg in three to six days and bores its way into the skin of the host, at the base of the hair which carried the eggs. The actual method of entry of the larva into the host was for long a matter of conjecture and the erroneous idea that the animal licked the eggs and so conveyed the parasite to the mouth was held for many years. The work of Carpenter in Ireland (*J. Dept. Agric. and Tech. Instr. Ireland.*, xv., 1) and of Bishopp and Laake in America ("The Cattle Grubs or Ox Warbles: their Biologies and Suggestions for Control," *U.S. Dept. Agric. Bull.*, 1369, 1926) has shown that the larvæ burrow directly through the skin and thus enter the body. They then work upwards in the connective tissue, appearing in the chest and abdominal cavity about two months later, during which time

BOT AND WARBLE FLIES (*Continued*)—

they have passed through two stages in the larval life. The next migration is to the subcutaneous tissues of the back, which is carried out fairly quickly. Once there, the larvæ enter upon a third stage which lasts about five days; a hole is then cut in the hide of the host and the "warble" or swelling in the back of the animal is formed, in which the fourth and fifth stages of larval development are passed. The total period in the back is about thirty-five days; during this time the larva feeds on the fluid arising from the inflammation caused by its presence.

In England the warbles begin to appear in the backs of the cattle from January and February onwards and occasionally earlier. The larvæ are full grown and ready to leave the warble in April and May; when full fed the grubs emerge through the breathing hole cut in the hide and fall to the ground, where they pupate, the adult flies appearing after about thirty-five days. The whole life cycle of the Warble Fly is thus seen to occupy a year, of which nine to eleven months are spent as a larva within the body of the host.

Hypoderma bovis de Geer.—A similar insect to the foregoing, but larger and stouter, it can be distinguished from *H. lineatum* by the yellow terminal hairs of the abdomen. The egg is attached singly to a hair by a rather elbowed stalk. The larva resembles that of *H. lineatum*, but is slightly larger and less spiny, there being no spines at all on the two last segments of the body, while in *lineatum* the last segment only is bare; it also differs in the appearance of the posterior spiracles. The life history of this species is very similar, except that the larvæ of *H. bovis* seldom enter the gullet of the host, and the adult flies are on the wing about a month later.

Injuries to the Host by Warble Flies—Bishopp classes the injuries caused to cattle by Warble Flies into four groups:

1. Soreness and pain produced by the penetration of the young larvæ through the skin of the leg.

2. Irritation produced in the gullet and in other internal organs by the migrating larvæ.

3. Inflammation produced along the spinal cord and on the main branches of the nervous system by the burrowing of the larvæ along the spinal canal, and at the ingress and egress of that canal.

4. The irritation produced by the later larval stages in the subdermal tissues of the back with accompanying pus formation.

To these may be added the loss of condition due to "gadding" or the efforts of the animal to escape the fly.

Preventive and Control Measures—Preventive measures against Warble Fly are of two kinds; the first and most practical measure lies in the provision of shelters into which the cattle will go to avoid being "struck" by the fly. The other preventive consists in the application of deterrent chemicals to the body or legs of the animal to ward off the fly; so far these have not proved sufficiently practical or efficacious to warrant further consideration here. Control measures consist of attacking the larvæ in their most vulnerable position, *i.e.*,

BOT AND WARBLE FLIES (*Continued*)—

in the backs of the cattle, from February to June. The other possible method of control is by the introduction of legislation.

As regards the eradication of the larvæ in the warbles, this can be effected by squeezing out the ripe maggot through the breathing hole in the hide or by killing it in the warble by the application of dressings; the latter seems to be the method which offers the greatest possibility of success, and it will be dealt with in some detail. Dressings should be applied at intervals of two or three weeks, about five in all being necessary, and it is important to see that the fluid penetrates the hole and comes into contact with the larva. In the *Report of the Departmental Committee on Warble Fly Pest* (*Min. Agric. and Fish., H.M. Stationery Office*) the following dressings are recommended as giving the most satisfactory results.

1. *Tobacco Powder and Lime*—This is made up in the following proportions: 4 lbs. tobacco powder, 1 lb. lime, and one gallon of water; this should be allowed to stand for twenty-four hours before being used. The solution must be made up freshly as required; it will not keep.

2. *Derris Root*—This is a powder, and has the advantage over the above dressing of being more easily handled. It should be applied mixed with water either alone, or as recommended by Gaut and Walton ("Ox Warble Fly: Report on the Demonstrations and Experiments carried out in Worcestershire," *Dept. Agric. Educ.*, Shirehall, Worcester), mixed with soft soap as follows: powdered derris 1 lb., soft soap ¼ lb., water 1 gallon.

3. *Nicotine Sulphate and Lime*—Nicotine sulphate 2 fluid ozs., calcium hydrate 1 lb., water 1 gallon. This, like the tobacco and lime, should be prepared freshly for each occasion.

These three fluid dressings are best applied by means of a brass syringe, and injected directly into the warble through the breathing hole in the hide. Bishopp in America has achieved good results by the use of an ointment consisting of iodoform 1 part, and vaseline 5 parts.

As regards possible legislative measures in Great Britain, these are not considered advisable at the moment, partly because proposals for compulsory action in the use of fly deterrents are not practical, and partly because there exists no control over the importation of "warbled" animals from other countries.

It cannot be too strongly emphasized that the co-operation of agriculturists is needed to exterminate the warble fly pest; isolated effort is of little use, while a few years' steady work on maggot destruction over a wide area would do much towards exterminating the pest.

THE HORSE BOT FLIES—There are three species of bot fly, the larvæ of which are parasitic in horses; these are *Gastrophilus intestinalis* de G. (*equi* F.), the Common Horse Bot Fly; *G. hæmorrhoidalis* L., the Nose Bot; and *G. nasalis* L., the Throat Bot.

Gastrophilus intestinalis de G. The Common Horse Bot Fly.

Description—This is a large hairy fly about ⅝ inch in length. The head is covered with a silvery pubescence which is brightly shining

BOT AND WARBLE FLIES (*Continued*)—

in life; the thorax is brownish with two tufts of erect bristles, and the abdomen also is brownish with short yellow pubescence. The wings have an S-shaped smoky band across the centre, a point of difference from the other two species. In the female of all three species the abdomen is characteristically elongated. The egg is whitish or ochreous and boat-shaped; it is attached to the hair by two flanges running for *two-thirds* the length of the egg. The larva or maggot is yellowish and barrel-shaped with eight segmented rows of spines, two girdles of spines on each segment. The puparium or chrysalis is jet black, smooth, and shiny.

Life History—The flies appear in the summer and oviposit on horses, the favourite position being low down on the inner face of the forelegs, but eggs are also deposited along the line of the belly and on the shoulders. The eggs hatch by friction, and this is brought about by the horse rubbing its legs and incidentally the eggs with its lips.

Hatching takes place in about seven days; it is not quite clear how the resulting larvæ reach their goal, which is the stomach of the horse. Hadwen and Cameron (*Bull. Entom. Res.*, ix., 1918) consider that once on the animal's lips the maggots burrow under the tongue, but their subsequent journey to the stomach has not been traced. The larvæ live for nine or ten months attached by their mouth hooks to the wall of the pyloric end of the stomach, passing out with the fæces when full fed. They turn into the chrysalis below the surface of the soil, the flies hatching out in three to ten weeks according to temperature conditions.

The Nose Bot Fly (*G. hæmorrhoidalis* L.)—A very similar fly to the foregoing, but may be distinguished by a yellow band across the base of the abdomen, and by the absence of any markings on the wings. The egg is dark in colour and is attached to the hair of the host by a grooved stalk. The life history is very similar to that of *G. intestinalis*, but differs in detail; the eggs are deposited singly on the hairs surrounding the lips, especially the lower lip, of the horse. The larvæ hatch without friction and make their way to the stomach, where they remain attached for some time, later they migrate to the rectum and become re-attached there, finally attaching themselves for two or three days close to the anus, where they protrude to the exterior. They then become detached singly, at any time, and fall to the ground, where they pupate.

The Throat Bot Fly (*G. nasalis* L.)—In this insect the thorax is brownish black with dense shiny orange pubescence, the abdomen bears on its apex some bright orange hairs, and the wings are without markings. The egg is yellowish-white and is attached to the hair by two flanges which run the *whole length* of the egg instead of two-thirds as in *G. intestinalis*. The eggs are deposited on the hairs beneath the jaws and hatch without friction. It is thought that the young larvæ bore through the skin and so make their way into the stomach, where they remain until the following spring, when they pass out with the fæces (F. C. Bishopp and W. E. Dove, "The Horse Bots and Their Control," *U.S. Dept. Agric. Farmers' Bull.*, 1503, 1926).

BOT AND WARBLE FLIES (*Continued*)—

Methods of Treatment and Control of Horse Bot Flies—The health of horses suffers considerably from the presence of large numbers of bot larvæ in the stomach, which may give rise to very severe inflammation, and the flies are also responsible for considerable secondary damage due to the fear and annoyance consequent upon their presence. The provision of fly shelters such as darkened sheds is recommended; as regards the eggs deposited on the animals, these may be destroyed by clipping or singeing, but a more thorough method is to rub the affected parts with a cloth dipped in a 2 per cent. solution of any standard coal-tar creosote dip.

For internal treatment of an affected horse Hall and Avery (*J. Amer. Vet. Med. Assoc.*, 1919) recommend carbon bisulphide in three doses of 3 drachms each at intervals of one hour; two doses of 4 drachms each at intervals of two hours, or a single dose of 6 drachms. The carbon bisulphide should not be followed by a purgative, and oil is especially undesirable. It is advisable for a veterinary surgeon to administer the doses.

The last fly of the *Œstridæ* to be considered is the Sheep Nostril Fly, *Cephalomyia* (*Œstrus*) *ovis* L.

Description—This is an insect of characteristic appearance measuring about ½ inch in length; the thorax is brownish and densely covered with black wart-like tubercles. The abdomen is black or brownish, marbled with white, and possessing a silvery lustre when the insect is alive. The wings, which are clear and glassy with yellow veins, extend beyond the abdomen when closed. The larva is yellowish in colour, convex dorsally and somewhat flattened ventrally; there is a transverse dark mark dorsally on each segment, while on the under surface of the abdomen are numbers of backwardly directed spines. When full grown the larva measures about 1 inch in length.

Life History—The fly is larviparous, depositing living maggots, not eggs, within the nostrils of sheep; it is particularly active in hot weather. The young larvæ make their way into the frontal sinuses of the head, where they attach themselves by their mouth hooks to the mucous membrane; here they remain for about nine months, passing through three larval stages or instars.

When the larva is mature it releases its hold and falls to the ground or is sneezed out by the sheep. Pupation takes place in the soil near the surface, or under stones and grass tufts, the fly emerging after twenty-one to sixty days according to temperature conditions.

Symptoms of Attack and Methods of Control—In districts where the fly is prevalent the sheep attempts to escape the insect by keeping its head close to the ground, generally in dry, dusty places. This has the effect of making the nostrils dusty and giving rise to catarrh. Sheep which are already affected often exhibit a discharge round the nostrils, accompanied by a difficulty in breathing; they may also suffer from a kind of fit known as "false gid." Preventive measures are the most practicable; one method is to smear the sides of a narrow salt trough with tar, so that the sheep is compelled to rub its nose in it to reach the salt; this is said to have a repellent effect upon the

BOT AND WARBLE FLIES (*Continued*)—

fly. Rapid rotation of pasture and the provision, in the case of a small flock, of shelters are also good preventive measures in a fly area. As a control measure, mercury bichloride at the rate of 1 part to 1,000 parts of water injected into the nostrils is sometimes successful.

K. M. S.

BRANK—See Buckwheat.

BRASSICÆ, MORPHOLOGY AND GENETICS OF—The genus *Brassica* has been in cultivation from the earliest times; Aristotle (and Pliny following him) described forms which can almost certainly be identified with familiar garden plants of to-day. Since almost all the garden and agricultural Brassicæ are to be found figured in the early herbals, it is clear that their origin is both remote and obscure. As regards the cabbage group, it is usually confidently asserted that the different forms have all been produced from the wild *B. oleracea* of the sea shore (Plate IV, Fig. 1); but for this statement there is no direct evidence either from experiment or from observation in nature. All that can be said is that the sea-shore cabbage is the only known wild type of *B. oleracea*, and that it readily crosses with all the cultivated races.

The *Brassica* group is distinguished from its near relation *Sinapis* (the mustard group) by having more or less erect sepals, whereas the mustard flowers have widely spreading sepals. This is almost the only distinguishing botanical feature. Although in a general way the cabbage group with its heavy glaucous foliage and long-drawn-out inflorescence is obviously different from the mustards with their slender hairy foliage and flattened inflorescence, there are too many intermediate varieties to allow any satisfactory botanical demarcation to be made on general morphological lines.

Leaving on one side, then, the mustard group and coming to *Brassica* proper, the agricultural varieties fall into three groups—the Cabbages, the Swedes, and the Turnips. The Cabbages (*B. oleracea*) comprise all the familiar garden vegetables (brussels sprouts, cabbages, savoys, and broccolis), as well as the well-known farm crops thousand-headed kale, kohl rabi, and marrow-stem kale. The Swede group (*B. Napus*) includes, besides the swedes proper, the common rape and the colza or oil-bearing rapes. The Turnip group (*B. rapa*) similarly includes both turnips proper and also the rapes which have turnip-like foliage. It is important to notice that the rapes, which at first sight might be taken to constitute a fourth group by themselves, botanically considered divide themselves between *Napus* and *rapa*.

It is difficult to make any exact morphological distinction between these three groups. But that they do, notwithstanding, constitute true species is none the less sure, since *oleracea* never crosses with either *rapa* or *Napus*, while *rapa* and *Napus* can only be crossed with difficulty and then give peculiar, nearly sterile hybrids to which reference will be made later. The cytological distinction is, however, definite: *Napus* has 36 chromosomes in the diploid phase, *rapa* 20, and *oleracea* 18 (Winge, "Contributions to the Knowledge of Chromosome Numbers in Plants," *La Cellule*, xxxv., 1924). (See Cytology.)

BRASSICÆ, MORPHOLOGY AND GENETICS OF (*Continued*)—

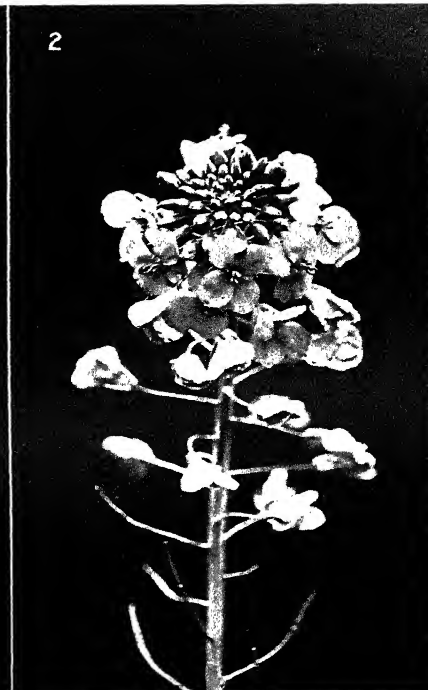
The most certain diagnosis between these groups depends on the changes which take place in the foliage during growth. *B. oleracea* is glaucous with a bluish-green (or purple) foliage at all stages in its growth. In *Napus* and *rapa* the colour of the cotyledons and first few true leaves is a bright clear green, and the leaves are hairy. But as the plants throw up more leaves, the *Napus* foliage loses its hairs, becomes smooth, and turns a distinctly blue-green; but the *rapa* leaves remain bright green and hairy throughout the life of the plant. When the plants come into blossom, *oleracea* and *Napus*, on the one hand, have elongated inflorescences in which the axes of the flowers are nearly horizontal (Plate III, Figs. 1 and 2); on the other hand, in *rapa* the raceme is flattened and the flower stalks turn up, so that the axes of the flowers are more or less vertical (Plate III, Fig. 3). It will be seen that it is the *Napus* group which causes the difficulty of distinction—for in the seedling stage it resembles *rapa* and in the flowering stage *oleracea*.

The cultivated races of *B. oleracea* constitute a group of forms so diverse that at first sight it is difficult to believe that they should all be one species. But in spite of their outward diversity all the known forms are readily crossable with one another and every gradation from one form to the other can be obtained by hybridization—though some combinations of characters seem to be difficult to synthesise. The ordinarily cultivated types, however, usually breed tolerably true (and by careful isolation they can be obtained quite pure). They are generally classified as follows:

1. **Kales**—This group comprises thousand-headed kale (Plate IV, Fig. 2), Jersey kale, curly kale, and such like types; it would seem to stand nearest to the wild type, the modifications being but relatively slight. Thousand-headed kale (*q.v.*), as its name implies, is a much branched leafy plant, popular as a sheep feed in the Eastern Counties, where it withstands both a dry summer and a cold winter. Jersey kale has but a single tall, hard stem bearing a crown of leaves which ultimately runs up into an inflorescence. In curly kale the margins of the leaves seem to have been stimulated to an altogether disproportionate growth, with the result that the leaf edge is thrown up into a more or less compact mass of folded tissue. In different cultivated varieties this abnormal leaf growth occurs in varying grades, ranging from a mere marginal crinkle up to the extreme type in which the leaf comes to look like a sponge. Portugal kale is a type which has broad cabbage-like leaves in which the mid-ribs have become enlarged and fleshy. These swollen mid-ribs are held by some to be a table delicacy not much inferior to asparagus. Finally there is in cultivation a large group of ornamental kales, in which the leaves are deeply laciniate, and are as well usually both purple and variegated; every combination and gradation of these characters is known, and some types on account of their graceful foliage have certainly some claim to be regarded as ornamental.

2. **The Cabbage**—In this form the terminal leaves are folded closely one over the other, so that a dense head or heart is formed terminally.

PLATE III.



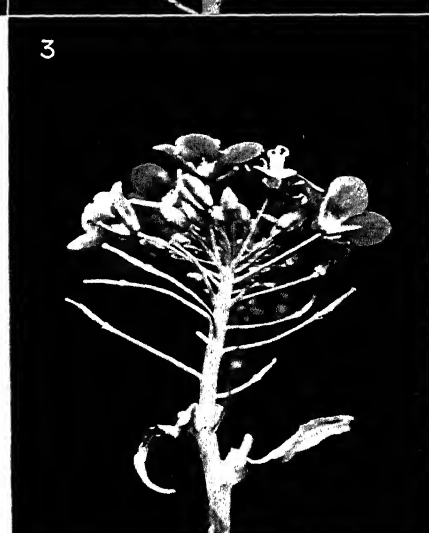


FIG. 1.—*BRASSICA OLERACEA.*

FIG. 2.—*BRASSICA NAPUS.*

FIG. 3.—*BRASSICA RAPA.*

To face p. 186

PLATE IV

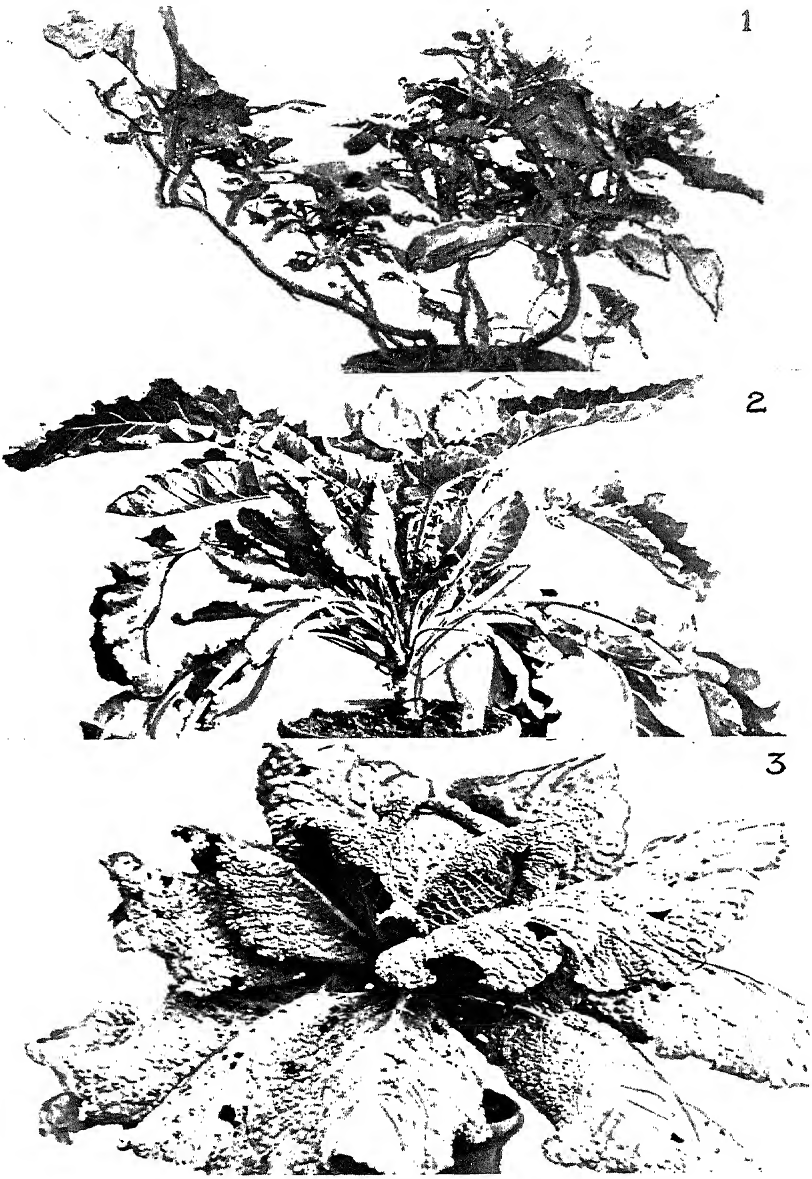


FIG. 1.—WILD *BRASSICA OLERACEA* OF THE SEA SHORE.

FIG. 2.—THOUSAND-HEADED KALE.

FIG. 3.—SAVOY CABBAGE.

To follow Plate III.

BRASSICÆ, MORPHOLOGY AND GENETICS OF (*Continued*)—

This is usually flattened (drumhead type) or pointed (oxheart type), and may be obtained in any size from a few inches to a couple of feet across. The larger forms are used for cattle feed—the smaller and more delicate ones for human consumption. To produce the ordinary cabbage for autumn and winter use, the seed is sown in spring and the seedlings put out in the field in early summer. But there are special varieties which, when sown in August and planted out in October, form the characteristic heart in the following May and June. This is a very favourite market garden crop, as owing to the high prices of fresh vegetables in early summer it is a very profitable one for a farmer placed conveniently near to a town. (See Cabbage Family, under Market Gardening.)

A proportion of the crop, however, is nearly always lost owing to "bolting"—the plants run up into blossom without forming any heart. This is primarily a hereditary defect, indeed Sutton (*J. Heredity*, xv.) regards it to be a simple Mendelian recessive, so that careful testing and isolation of seed plants is the only certain safeguard.

3. **The Savoys**—In form these are usually cabbages, but the distinguishing characteristic is the peculiar blistered leaf (Plate IV, Fig. 3), which would seem to be brought about by the upper surface of the leaf growing out of proportion to the network of veins which forms the rigid frame of the leaf. Thus the surface of the leaf is thrown up into a mass of blisters. There is some variation in the intensity of the blister in the various strains of savoys. While it is usually associated with the cabbage type, this leaf monstrosity is also found amongst kales, *e.g.*, in palmbaum, a form commonly grown in Germany; moreover, by crossing, this leaf characteristic can be transferred to other types.

4. **Brussels Sprouts**—In this group the hearting abnormality of the cabbage is found not in the terminal shoot, but on the lateral shoots (Plate V, Fig. 1). The common Brussels sprouts is a very favourite autumn and winter vegetable and is one of the principal crops in market garden areas. By hybridizing with the cabbage, a type has been extracted in which the terminal shoot also makes a heart, and in some parts this variety has found favour with the growers.

5. **Kohl Rabi**—The common name for this plant—cabbage turnip—sufficiently explains this type (Plate V, Fig. 3). The characteristic swollen stem or "bulb" is a favourite sheep feed in the Eastern Counties, where it manages to thrive on a rainfall altogether too scanty for the moisture-loving swede. Smaller and more delicate forms make a favourite vegetable for the table, especially on the Continent. Marrow-stem kale (*q.v.* also Plate V, Fig. 2) represents an intermediate condition between kohl rabi and kale. This plant stands 3 to 5 ft. high, the whole stem being swollen and forming a large weight of food for stock.

6. **The Broccolis**—This group is characterized by a grossly fasciated inflorescence (in which most of the flowers are abortive), the whole in its early stage forming a dense mass of white, delicate edible tissue. According to the time of flowering and their hardiness the plants

BRASSICÆ, MORPHOLOGY AND GENETICS OF (*Continued*)—

are called cauliflowers or broccoli—but this distinction is arbitrary. Cauliflowers come in summer and early autumn, broccoli in autumn and winter, and, being hardier, last through to spring. They form an increasingly important crop in Cornwall, where the mild weather favours their winter growth. Sprouting broccoli is an intermediate condition between the normal inflorescence and the extreme fasciated condition of the broccoli proper. So that instead of being a compact mass the inflorescence breaks up into a multitude of sprouts, all more or less fasciated.

Recently a perennial branching type of broccoli has been put on the market, but has not so far come into general use. In general growth and form the plant is not unlike the wild cabbage. The broccoli heads are produced irregularly on the branching shoots, which remain alive and "bearing" for several years.

Of the relationships of these various types of *oleracea* to one another very little is known, except that it is not a simple matter (Kristofferson, *Hereditas*, v.; Pease, *J. Genetics*, vol. xvi.; Malinowski, *Mémoires de l'Institute de Génétique*, vol. i.). All the types are readily crossable *inter se*, but very few cases of clear-cut single-factor differences have been found. In crosses between the usual types the hybrids are intermediate, and when bred on give every gradation of type, the parental forms being but rarely recovered. This shows that many Mendelian factors are involved. It is worth recording that so far some combinations of characters have not been produced, *e.g.*, the kohl rabi bearing a perfect cabbage head, or a cabbage with the extreme foliage of the curly kale. This would seem to show that complex linkages are involved.

However, this much is fairly certainly: known white flowers are dominant to yellow (Pearson, *American Naturalist*, vol. lxiii.), the purple pigment (such as that of the red cabbage) is dominant to green (Kristofferson, *loc. cit.*), in some cases two complementary factors are involved (Pease, *J. Genetics*, vol. xvii.). The laciniate foliage of the ornamental kales is dominant to the normal, as is also the variegated condition (author's experiments, unpublished). In these cases segregation is sharp and is unaffected by ordinary seasonal and cultural conditions: they are clear cases of single-factor differences.

But the characters which differentiate the main groups—the heart of the cabbage, the bulb of the kohl rabi, and the fasciated inflorescence of the broccoli—are all dependent on many factors which are themselves very sensitive to changes in the environment. Various factorial schemes have been suggested for these major differences (Malinowski, *loc. cit.*; Pease, *loc. cit.*; Allgayer, *Zeit. f. Ind. Abs. und Ver.*, vol. xlvii.), but they are all uncertain and to some extent arbitrary, depending, as they necessarily largely do, on each experimenter's classification of the vast array of intermediate grades.

The swede group may be broadly divided into swedes proper and rapes. The swedes have the characteristic swollen hypocotyl, which becomes the organ of storage for the winter, while the rapes are bulbless, running straight up into blossom from the rosette stage,

PLATE V

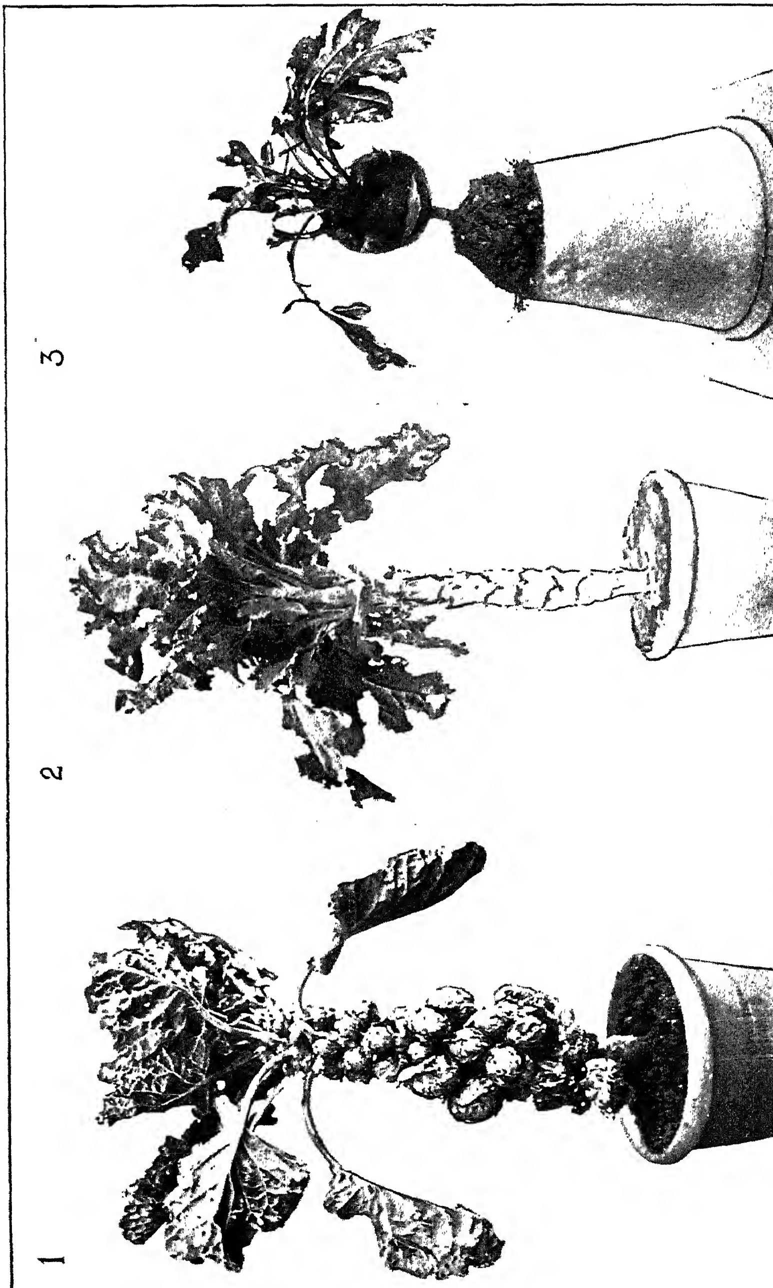


FIG. BRUSSELS SPRO

FIG MARROW-STE KALE

FIG KOHL RAB

BRASSICÆ, MORPHOLOGY AND GENETICS OF (*Continued*)—

but it should be noticed that this is not an absolute distinction, since swedes sown in August grow to the rosette stage before winter, and in the following spring run up to flower without forming any "bulb." It is worth pointing out that this would be the normal life cycle in nature, and it is quite likely, therefore, that swedes have "existed" in this form from time immemorial; it was only when man interfered with the course of nature by keeping the seed through the winter and sowing it in the spring that the bulbing potentiality of the swede had a chance to come into action.

Swedes are variously coloured externally, the tops and necks of the bulb being green, bronze, or purple, while the flesh is white or yellow. The flowers are lemon yellow or buffish, yellow being a simple dominant (Sylven, *Hereditas*, ix.); but the flower colour is always associated with the flesh colour, yellow flowers going with white flesh and buff with yellow flesh.

Trouble is sometimes experienced due to a certain proportion (varying from 10 to 70 per cent.) of the swedes failing to produce bulbs and behaving apparently as rape plants (Plate VI, Fig 2). Nothing is known for certain regarding the cause of this, beyond the fact that these rape-like "reversionary" plants breed true; when selfed and bred on they have never again given swedes (author's own experiments, unpublished). This would point to some induced mutation in the seed or perhaps merely to contamination. The seedsmen confidently ascribe the trouble to faulty cultivation, and the farmers equally confidently blame the seed. While nothing certain is known about the cause of the trouble, it is worth noticing that swedes when grown for seed are sown in the late summer, so that no bulb is formed before the plants flower in May: this procedure (which avoids loss due to the bulbs rotting away in the winter) also precludes any "roguing" for the bulb character, and it is exactly this character in which swede seed would appear from time to time to be impure.

The turnip, like the swede, flourishes in the wetter parts of the British Isles, where it forms a common and reliable field crop. The "bulb" of the turnip is distinguished from that of the swede by having no neck; the crown of leaves arises directly from the bulb in the turnip: in the swede there is always a well-marked neck which bears the leaves. The turnip group, like the swede group, includes both a bulbed type (the turnip proper) and a bulbless type or turnip-like rape. As in the swedes so in the turnips, the distinction between the bulbed and bulbless forms depends partly on the time of sowing (L. H. Bailey, "The Cultivated Brassicas," p. 86). Moreover, there exists in the turnips both yellow and buff flowers, associated in exactly the same way with white and yellow flesh colour. The swede and the turnip, and to a less extent the cabbage groups, illustrate nicely the law of homologous variations (Vavilov, *J. Genetics*, vol. xii.), as the table on p. 190 shows.

It has already been mentioned that whereas *oleracea* does not cross with either *Napus* or *rapa*, *Napus* and *rapa* can be crossed together fairly easily (Sutton, *J. Linnean Society* (Botany), 1908). When

BRASSICÆ, MORPHOLOGY AND GENETICS OF (*Continued*)—
swede is used as the ovule parent, seed sets moderately well and germinates without difficulty. When, however, the cross is made in the other direction the seed sets but poorly and germinates reluctantly. In both cases the hybrid root is usually a monstrous, misshapen, fanged structure, covered with irregular nodular outgrowths from which leafy underground shoots arise (Kajanus, *Zeit. f. induk. Abst. und Ver.*, 1912). Plate VI, Fig. 1, shows such a plant grown by the author. The hybrid plant is difficult to keep through the winter, since it nearly always falls a prey to rot. But where the hybrid has lasted through to flowering time, it has been found to be sterile, at least when pollinated with hybrid pollen—though some seed has been obtained by using either turnip or swede pollen.

TABLE TO SHOW HOMOLOGOUS VARIATION.

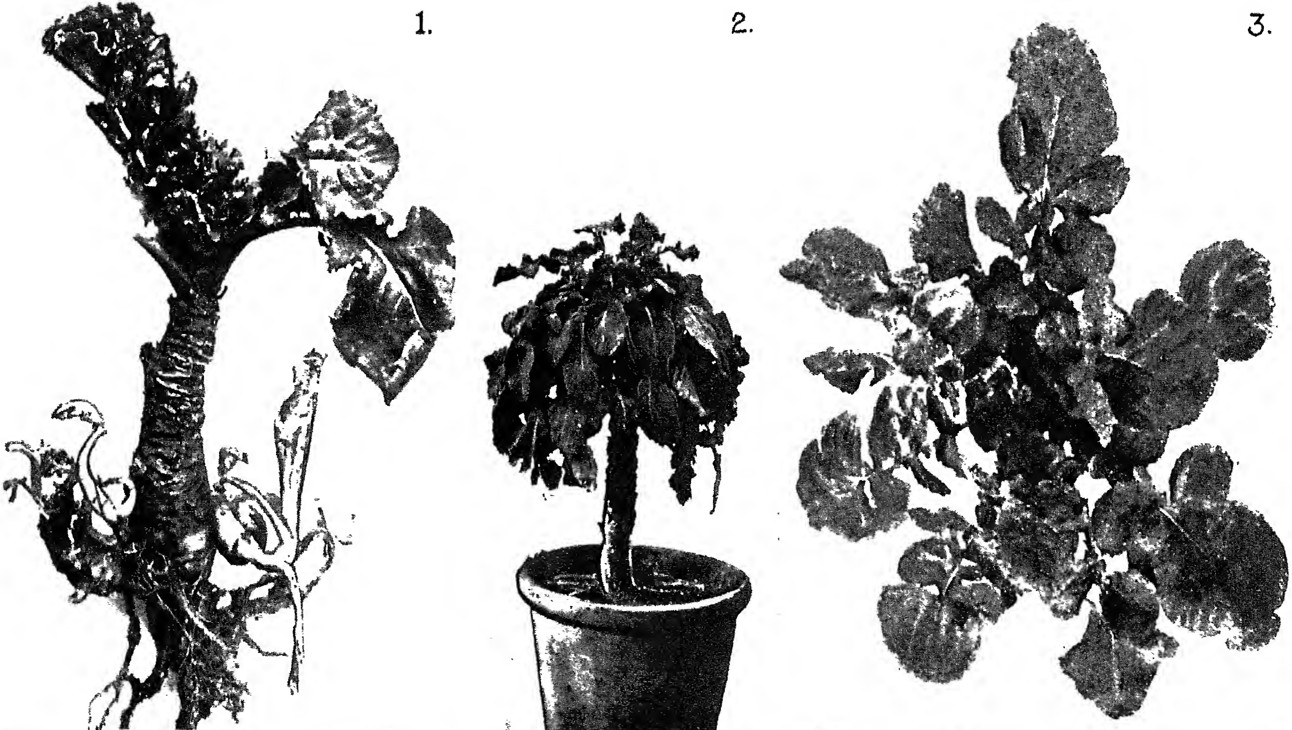
	B. oleracea.	*B. Napus.*	*B. rapa.*
Flower colour	White Yellow —	— Yellow Buff	— Yellow Buff
Flesh of bulb	White —	White Yellow	White Yellow
Normal stem .. .. Swollen stem	Kale Kohl rabi	Swede-like rape Swede	Turnip-like rape Turnip
Leaves laciniate	Ornamental kale	Ragged Jack kale	—
Leaves curly	Scotch kale	Wibberley's kale	—

The peculiar "hybridization nodules" mentioned above formed the subject of much unsatisfactory speculation until quite recently, when it was shown by A. W. Bartlett (*Trans. Brit. Myc. Soc.*, vol. xiii.) that these nodules are caused by the invasion of a minute fungus, *Olpidium radicicolum.* The odd feature is that the fungus is not to be found in the nodules themselves, but it invades the outermost layer of cells in the root hairs. Bartlett's infection experiments, however, satisfactorily show that the fungus is the true cause of the nodules. The striking thing is that whereas pure swedes, turnips, and other cruciferous plants are not commonly invaded by this fungus—at least not to any serious extent—the hybrid *Napus* by *rapa* is almost invariably fatally attacked by *O. radicicolum.*

As regards other species of hybrids in *Brassica,* it has been reported that *B. oleracea* by *B. sinensis* (Pet sai) gives a partially sterile hybrid, and that *sinensis* crosses readily and gives fully fertile hybrids with *rapa* (Ragionieri, *Gardeners' Chronicle,* 1920).

By far the most interesting and most fully analysed species cross in this group is the cabbage by the radish. This hybrid has been reported

PLATE VI



G SWED AN
'ot

NON-BULBING

3.—TETRAPLOID CABB
YBRID (FROM KARPECI

BRASSICÆ, MORPHOLOGY AND GENETICS OF (*Continued*)—
several times (Sageret (1826), *Ann. des Sci. Nat.*, viii.; and Moldenhawer, *Bull. Int. de l'Acad. Polonaise de Sc.*), but the matter has only recently been analysed by the studies of Karpechenko (*Bull. App. Bot., Genetics, and Plant Breeding*, vol. xvii.). Both *Raphanus* and *B. oleracea* have 18 chromosomes: Karpechenko showed that the F_1 hybrid plants also had 18 chromosomes. In F_2 and in the back crosses plants with higher chromosome numbers were obtained. Of these some were weak and showed obvious outward signs of disharmony. But some tetraploids (plants with 36 chromosomes) were obtained which behaved quite normally—they were fully fertile and bred more or less true (Plate VI, Fig. 3). The most interesting thing about them was that they could only with difficulty be crossed with either *B. oleracea* or with *Raphanus*. It is difficult to resist the conclusion that Karpechenko has here produced a *new species*, in the strict sense of the word. M. S. P.

BREAK—Arable land is usually worked on some fixed rotation based on the Norfolk four-course of roots, barley, clover, wheat. The portion of arable land under any one of the rotation crops is referred to as a "break," *e.g.*, turnip break refers to all the land on the farm under that particular crop.

BREWERS' GRAINS—For composition, feeding, and manurial value, see Feeding Stuffs.

BROW—The brow is the name given to the side of a furrow slice next the open or mould furrow. It is important that it should not be too upright or "proud," as the harrow may draw the furrow slice bodily into the open furrow, and so create difficulty in working the soil down into a fine tilth. (See Ploughing.)

BUCKWHEAT or BRANK (*Polygonum fagopyrum* L. or *Fagopyrum* spp.) derives its name from the German *Buch-weizen*, or "beech wheat," on account of the general similarity in appearance of the seeds of the two plants.

There are two cultivated species of the genus *Fagopyrum*:

(1) **Common Buckwheat,** *F. esculentum.*
(2) **Tartarian Buckwheat,** *F. tartaricum.*

(1) There are several varieties of the Common Buckwheat which differ chiefly in the height, branching habit, and colour of the stem, and in the form and colour of the fruit.

(*a*) The Common Buckwheat (*F. esculentum,* Gaertn.) is probably a native of Central or Northern Asia. It is an annual with succulent, hollow stems, greenish-red in colour, growing to a height of 2 to 3 ft. or more, according to the fertility of the soil, and turning brown as they ripen. The flowers are small and pinkish-white in colour; the seeds dark brown, and three-cornered in section, with remains of the perianth at the base. The plant possesses a rapid habit of growth, and reaches maturity in twelve to fourteen weeks from the time of sowing.

BUCKWHEAT (*Continued*)—

(*b*) Silver Grey or Silver Hull Buckwheat has a somewhat shorter and more branched stem with small darkish-grey fruits.

(*c*) Japanese Buckwheat, a tall green-stemmed variety with fruits in which the angles are extended into the form of small wings.

(2) Tartarian Buckwheat (*F. tartaricum*) is characterized by a taller stem than that of Common Buckwheat, and is claimed to be more hardy. The fruit is brownish-grey, with an elongated, wavy outline; the angles are rounded, not sharp as in Common Buckwheat, with depressions or furrows between them.

There is a comparatively small area devoted to buckwheat in the British Isles, and its cultivation is largely confined to the Fen districts and certain sandy areas in East Anglia.

Soil—Buckwheat is generally considered to be a suitable crop for light soils, and is in many cases grown on soil deficient in lime. At Tunstall Experimental Station in Suffolk, however, in 1930, the crop of buckwheat obtained on a portion of a very acid field (lime requirement 27 cwts.), which received a dressing of chalk at the rate of 5 tons to the acre, was at least double that on another portion of the same field which received no chalk. Further, the buckwheat on the unchalked portion appeared to suffer severely during the dry period from the middle of June until the middle of July. After the subsequent heavy rains the crop on the unchalked portion of the field recovered and made good growth.

Although buckwheat is perhaps most generally grown on light soils, it is found in considerable quantities on Fen land and on medium loams.

Position in Rotation—If the production of grain is the object in view, it may be sown after a root crop; whilst if grown for sheep feed or as a soiling crop, it may take the place of roots.

Sowing—Buckwheat is very sensitive to frost, and consequently is not sown until from the middle to the end of May. When grown for seed, the crop is not usually fit to harvest until September; it is not advisable, therefore, to delay sowing beyond a safe date in May, otherwise the chance of harvesting the crop fully ripened and in good condition is seriously reduced. The seed is drilled at the rate of 1 to 2 bushels (=approx. 4½-9 stones) per acre after the land has been ploughed and cleaned.

Manuring—On fen soils and on well-farmed land, buckwheat requires no manure, but when grown after a cereal on poor, light soil, it has been found to respond to nitrogenous manuring. At New Jersey Agricultural Station it has been found to possess considerable powers of assimilating insoluble rock phosphate.

If grown for grain, it is undesirable to over-manure the crop, for it is liable to become laid, and is then difficult to harvest; when grown for sheep feed or for soiling, a laid crop is not such a disadvantage, but should be avoided as far as possible.

Harvesting—The crop should be cut when the majority of the seeds are ripe, and before they begin to fall. Birds are extremely partial to

BUCKWHEAT (*Continued*)—

the grain, and on small areas serious losses may be sustained by their depredations, particularly before the crop is cut.

Cutting is frequently done by the scythe or side-delivery reaper. As the stems of the plant are succulent and difficult to dry in wet weather, they are preferably left untied, but in many cases the crop is cut and tied in the same way as cereals. When dry the crop should be made up into small stacks arranged in such a way as to facilitate the free circulation of air; faggots, hurdles, and layers of straw may be introduced into the stack to assist in drying.

Utilization of the Crop: (1) Grain—The yield of grain is subject to wide variation; on poor soil it may be 10 cwts. or even less per acre, whilst on better soil double this quantity may be produced. In the British Isles the grain is used almost entirely for poultry and game, but on the Continent and in America the flour, after milling, is utilised for bread and cakes for human consumption. As poultry food, buckwheat has always enjoyed a considerable reputation, and is claimed to produce a white flesh. In composition it closely resembles oats, but is rather higher in fibre and lower in ether extract. (See Foodstuffs.) Crushed or ground buckwheat may be mixed in small quantities with other foods for most farm animals, but when eaten in too large quantities it is liable to cause digestive troubles.

(2) **Forage**—After threshing, the "straw" of buckwheat is fed to all classes of stock, and is consumed with relish. On light land buckwheat is useful for inclusion in mixtures with other plants for sheep feed or for feeding to cows as a soiling crop. It may also be made into silage or ploughed in as a green manure. In Suffolk a seeding of ½ bushel of buckwheat has proved an excellent addition to rape and mustard, and sheep have been found to succeed well on it. A mixture of ½ bushel of buckwheat and 1 bushel of lupins has also produced a useful food for sheep.

Apart from any value attaching to the crop as a grain or fodder producer, it is useful as a means of smothering weeds. The cultivations preparatory to sowing check the first growth of annual weeds, whilst on good land, by its rapid development and the manner in which it grows together, buckwheat excludes the light to such an extent as to retard the growth of weed plants. Although the roots of buckwheat do not penetrate deeply, they leave the soil in a very friable condition.

As buckwheat is not sown until late in May, it provides a most satisfactory means of utilizing portions of fields which for various reasons were left unsown, and of resowing such portions on which another crop has failed.

Finally, there are well-developed nectaries inserted around the base of the ovary of the flowers, and the crop thus provides abundant food for bees during an extended flowering period.

Improvement of the Crop—Owing undoubtedly to the very limited cultivation of buckwheat in the British Isles, no serious attempt has been made to improve the crop yet. In Russia, where large areas are cultivated, the crop has been subjected to selection on the basis of

BUCKWHEAT (*Continued*)—

grain weight, and certain improved lines have been introduced into general cultivation ("Plant Breeding and Seed Growing in U.S.S.R., 1914-23," Leningrad, 1924).

Investigations, preparatory to more systematic attempts at improvement, have been made and reported upon (*Bulletin of Applied Botany and Plant Breeding*, Leningrad, vol. xiv., 1924-25; vol. xxi., 1929). A. W. O.

BULB GROWING, Areas of Distribution and Economic Features—It has been customary for a great many years to regard Holland as the principal source of all kinds of bulbs, particularly those of the daffodil, narcissus, tulip, and hyacinth, which are employed in considerable quantities every year for the commercial production of flowers, not to mention the very large quantities which are annually absorbed by the owners of private gardens. The Dutch growers retained this trade largely because of the specialized nature of the industry.

Bulb production on a commercial scale involves a substantial measure of highly developed technique, but at the same time it must be borne in mind that the conditions appertaining to the soil in many parts of Holland were decidedly favourable to the industry, and without these suitable soil conditions bulb growing cannot be wholly successful. There are, however, in Great Britain several districts possessing conditions as to soil and climate somewhat similar to those of the bulb-growing districts of Holland, the most prominent of which are the Holland division of Lincolnshire and the Wisbech district of the Isle of Ely, where the vast tracts of marine silt possessing a high water table supply conditions differing but very little from those of their Continental rival. Here in the Spalding area the cultivation of daffodils, narcissi, and tulips was commenced thirty to forty years ago. For some years, largely because of the fact that the growers lacked expert knowledge of the details of cultivation, the industry did not make very rapid progress. During the last ten years, however, very substantial progress has been made, and the industry now appears to be firmly established, and considerable quantities of bulbs are not only distributed throughout Great Britain, but are being exported to Holland and other countries in increasing quantities. These remarks apply to bulbs of daffodils, narcissi, and tulips, for although many attempts have been made, the successful production on a commercial scale of hyacinth bulbs in Great Britain has not yet been found possible, and these bulbs are still largely the exclusive crop of the Dutch bulb districts.

For the sake of comparison it must be admitted that the Dutch bulbs are usually larger in size and brighter coloured than those produced in England—features which render them both attractive and readily saleable. On the other hand, English bulbs usually contain more substance and less water, and are certainly capable of producing flowers of equal quality. Colour is, however, a very important feature, especially with the tulips, where it is essential that the bulb, when harvested, should "finish" with a bright chestnut colour. In this

BULB GROWING (*Continued*)—

connection it was found that the large tracts of black, fen soils in Cambridgeshire, while suitable in many ways for the production of tulips, yielded bulbs of a dull, unsuitable colour, and further cultivation had eventually to be abandoned mainly on account of this reason.

It was stated above that the Spalding district of Lincolnshire is the principal producing area for bulbs in Great Britain. The industry in this district was devoted originally to the production of flowers only, and it is only during the last decade that serious attention has been paid to the production of bulbs. The distinction in this connection is that the bulb grower cannot very well afford to be a flower grower as well. In other words, the production of flowers is found to affect the bulbs (especially those of tulips) to such an extent that it is essential that the flower buds should be removed immediately it is possible to make sure that no "rogues" exist in the crop, thus ensuring that all the strength of the plants is thrown into the formation of the bulbs.

The condition of the English bulb industry at the present time may be judged from the statement that it is estimated that the Lincolnshire and Isle of Ely districts now grow about 1,500 acres of bulbs, and it is known that these districts exported 2,500 tons of bulbs to Holland in 1929, and that a further 1,000 tons were distributed to home growers. The latter figure represents, of course, only a small proportion of the annual trade in bulbs in Great Britain, but there is no valid reason why the major proportion of this trade should not be secured eventually by home growers. It is estimated that 15,000 tons of Dutch bulbs are annually imported into this country, representing a value of roughly 1¼ millions sterling.

Another large bulb-growing area is in Cornwall, where, in the Tamar Valley and the district around Penzance, it is estimated that from 800 to 1,000 acres, principally of daffodils and narcissi, are grown. In these districts, however, owing to the mildness of the climate, the chief aspect of the industry is the production of early flowers for market.

The Scilly Isles is another bulb-growing area where flowers are made a speciality, these islands being a few weeks earlier than Cornwall.

Varieties—The varieties of daffodils, narcissi, and tulips most in demand are as follows:

Daffodils (trumpet-flowered group): **King Alfred, Emperor, Empress, Golden Spur, Victoria, Horsfieldii.**

Narcissi—Incomparabilis group: **Sir Watkin, Lucifer.** Barri group: **Conspicuous, Sunrise, Flame, Firetail.** Poeticus group: **Ornatus, Glory of Lissse, Recurvus.**

Tulips—English and cottage classes: **Bouton d'Or, Caledonia, White Swan, Gesneriana lutea, G. Major, G. Blue Star.** Darwin class: **Bartigon, Clara Butt, Farncombe Sanders, William Copeland, Pride of Haarlem, Mad Krelage, Elizabeth.**

General Cultivation—All classes of bulbs do best in a fine, sandy loam which is moist yet well drained. A fairly high water table

BULB GROWING (*Continued*)—

appears to be a distinct advantage. The land should be in a high state of fertility, and should be very deeply worked. No better preparation of the land for bulbs could be given than to grow a preceding crop of potatoes to which a good dressing of farmyard manure is applied. It is important that no fresh manure of any kind should be put on for the bulb crop immediately before planting, and the residual value of the manure applied to the potatoes will bring the land into a condition exactly right for the bulbs provided the fertility elements are augmented by a dressing of fertilizers. Under average conditions a good mixture to apply is 2½ cwts. Peruvian guano, 2½ cwts. superphosphate (30 per cent. soluble phosphate), and 1½ cwts. sulphate of potash to the acre. Under certain conditions an additional application of 3 cwts. of basic slag is desirable, and on very sandy soils kainit has been found to be beneficial.

For narcissi and daffodils on the poorer types of land, a light dressing of a nitrogenous fertilizer applied just when the bulbs are shooting above the ground is of special value. This may be either sulphate of ammonia or nitrate of soda, and the application should normally not exceed 1 cwt. per acre.

Daffodil and narcissi bulbs are planted out on the flat in rows about 1 ft. apart, with only a few inches from bulb to bulb. In the case of large areas it is usual to plant in a furrow struck out with a light plough having a suitable attachment, and at such a depth as to give the bulbs a covering of from 4 to 5 ins. of soil. Each furrow is planted as the work proceeds, so that the soil from the one covers the other. Every seventh or eighth row should be left unplanted to provide pathways for inspection, cleaning, and other operations. Smaller areas may be planted with spade-made furrows in the same way. Until the bulbs are ready for lifting, which may be in one or two years from the time of planting, the beds should be kept clean and as free from weeds as possible, but it is not advisable to use horse-drawn implements for this purpose. By making use of the pathways between the beds, hand work should enable the grower to clean the beds without unduly damaging the bulbs.

One of the bulb grower's most important routine operations is "rogueing." This must be practised both at flowering time, in order to keep the stock pure and true to type, and throughout the growing season for the purpose of removing diseased plants.

All classes of bulbs should be lifted as soon as the foliage has fully died down, and in any case before root action is recommenced.

The bulbs should be ploughed or forked out, and they should be gathered and placed in shallow trays as the work proceeds. It is a mistake to leave the bulbs on the surface of the ground exposed to strong sunlight, wind, and rain. Instead, the trays of bulbs should be stacked in a cool, well-ventilated shed, from which strong light is excluded. Under such conditions the bulbs will ripen off with a "finish" as to colour and degree of firmness which will enable the grower to maintain a high standard of quality. At a later date the bulbs should be graded into firsts, seconds, and "chips"—offsets.

BULB GROWING (*Continued*)—

The firsts and seconds are saleable sizes, but the "chips" are usually reserved for replanting.

No account of bulb growing in Great Britain would be complete without a reference to the situation which was brought about by the Narcissus Eelworm [*Tylenchus dipsaci* (Kuhn)]. This pest commenced its attack on narcissus and daffodil bulbs in England about the year 1915 (it was unknown in Holland until 1919), and it rapidly developed into a very grave menace to the bulb-growing industry. As is generally the case with eelworms, it was discovered that the particular eelworm involved was a biologic form of *Tylenchus dipsaci* (an organism which is known to attack a great number of economic plants, including the potato), which confined its depredations to bulbs.

The problem it presented soon threatened the industry with extinction, and it is due entirely to the prolonged scientific research initiated by the late W. Ramsbottom that the growers' difficulties were overcome, and the bulb-growing industry was enabled to establish itself on sound lines.

The essential point regarding the Narcissus Eelworm is that bulbs once invaded remain infected and are ultimately destroyed, although this may take upwards of two years to effect. The investigations undertaken by Ramsbottom centred, *inter alia*, on the question of a possible treatment for the infected bulbs, and it was discovered finally that by immersing them for three hours in water heated to 110° F., the eelworms were destroyed, while the bulbs remained unharmed. As a result, the position to-day is that the eelworm pest is no longer feared, and all bulb growers possessing any appreciable acreage have installed suitable equipment for providing this hot-water treatment. With the aid of this equipment, types of which are now manufactured by several engineering firms, large quantities of bulbs may be dealt with rapidly. The treatment, although very simple, requires care, and the precautions for the grower to observe are that the bulbs should be absolutely dormant at the time of treatment, and after treatment they should be dried off and replanted on fresh uncontaminated soil, without delay. A gas-heated bulb sterilizer, suitable for handling 84 lbs. of bulbs at a time, may be purchased for about £12 10s.

It was pointed out above that the form of this eelworm which attacks bulbs does not attack any other crop plants, and it follows therefore that the introduction into uninfected soil of the bulb form is due entirely to the planting of infected bulbs.

Growers may safeguard their interest by recognizing that the only sure protection against infection is the adoption of the hot-water treatment in the case of all the bulbs they plant, as when once the land becomes infected there is no known means of eradicating the pest.

By practising this precautionary measure, coupled with scrupulous sanitary methods in disposing of suspected plants, decayed foliage and other rubbish, the bulb grower of to-day should have nothing to fear from this pest.

There are several fungus diseases of daffodils, narcissi, and tulips, but most of them are of minor importance and appear to flourish

BULB GROWING (*Continued*)—

best in damp, warm weather, and their effect, consequently, is not always felt.

The disease of tulips known as "fire," caused by *Botrytis tulipæ*, has, however, become more serious in recent years, and an increasing amount of destruction is being done by it annually.

Insect pests comprise the Large Narcissus Fly (*Merodon equestris*) and the Lesser Bulb Flies (*Eumerus strigatus* and *E. tuberculatus*), all affecting narcissi and daffodils, but they are all amenable to effective control. There is no important insect pest of tulips, but aphides may cause damage both to the growing crop and to stored bulbs.

BUNT OR STINKING SMUT OF WHEAT (*Tilletia caries*)—This disease, known to Theophrastus, as well as Vergil, Pliny, and other Romans, has received more attention from the philosopher and pathologist through successive ages than any other plant disease. For centuries the cause of it was shrouded in mystery. Numerous explanations were offered to account for it, and many and ingenuous methods of control were suggested. For example, one writer advocated sowing in the dark of the moon "in God's name." Fantastic as this may appear, it must be remembered that witches have been burned at the stake because they have cast "the evil eye" upon a neighbour's crops and "blasted" them. The true nature of Bunt became known in 1755, when the Abbé Tillet proved by experiment the infective nature of Bunt dust.

Briefly, the history and control of the disease is as follows: Bunt or stinking Smut of wheat is caused by a fungus, *T. caries*, which attacks the plant in the seedling stage. The mycelial threads of the fungus penetrate into the growing point, and are maintained in the developing plant and, later, in the rapidly growing seed, which is ultimately filled with millions of spores. In the threshing machine these diseased or bunted ears are broken up, and the healthy grain is contaminated with the liberated spores.

Control of the disease is simple, as all that is necessary is to kill the spores on the grain, and this can be effected in many ways. In agricultural practice the methods now advocated are as follows:

(*a*) Steeping or sprinkling the seed with a solution of formaldehyde; the strength recommended is 1 part of 40 per cent. formaldehyde to 40 gallons of water.

(*b*) Steeping or sprinkling the seed with a 2½ per cent. solution of copper sulphate, *i.e.*, 2½ lbs. of copper sulphate crystals to 10 gallons of water.

(*c*) Dusting the seed with copper carbonate powder at the rate of 2 ozs. of powder to a bushel of wheat. For this purpose a machine for mixing the dust and grain is necessary. Should further details of these treatments be required they will be found in *Leaflet* 92, *Min. of Agric. and Fish.*

The superstitions of the Middle Ages are long since dead, and yet in many quarters the infective nature of the Bunt dust is not fully recognized. For example, it is stated that the annual loss from Bunt

BUNT OR STINKING SMUT OF WHEAT (*Continued*)—
in the United States is still 25,000,000 bushels (Stevens, "Diseases of Economic Plants").

From what has been written it might appear that as the life history of the disease is known and the disease can be controlled further work on it was unnecessary. In the past decade, however, it has received much attention, as it has been the object of plant breeders in certain countries to produce Bunt-resistant hybrids. Large numbers of varieties have been tested, and some of them have shown marked resistance. Using these varieties as parents, American plant breeders have produced what they considered to be resistant hybrids. These, together with the parent varieties, have been tested in many parts of the world, and for some time it seemed that they were truly resistant. Lately, however, the writer has shown that under certain conditions these varieties are susceptible to the disease. It has been proved that the fungus is a complex system of different races, and that although a variety may be resistant to one race, it may not be resistant to another. There are, therefore, what are termed biologic races of *T. caries*. Although a wheat may be resistant to a particular strain of Bunt in the United States, it does not follow that it will be highly resistant in another country. Furthermore, it has been shown that a *resistant variety is susceptible to its own Bunt*. For example, if one of these resistant varieties, such as Ridit, becomes slightly infected, it is possible, by infecting the variety with its own Bunts in subsequent seasons, to render it still more susceptible. It has been shown that the repeated passage of this fungus through a given wheat variety "increases its virulency."

To account for these phenomena the writer has suggested that this pathogen is composed of races from which units (pure lines, perhaps) may be obtained, and it is thought that hybridization between these units may take place. Further, it is considered that such a unit is fixed, and that it does not increase or decrease in virulency, but is subject to change only when hybridization takes place. It is considered that every unit in the population of the parasite has a disease-inciting power of 100 per cent. on a particular strain of a host, and under certain environmental conditions. It is further suggested that increase in virulency is due to the selection of particular strains from the population of the parasite, and that maximum virulency is reached when the host is parasitized by its own strain of the pathogen. (See Diseases of Cereals, under Wheat; also Seed, Transmission of Plant Diseases by; and Insecticides and Fungicides.) W. A. R. D. W.

BURNET (*Poterium Sanguisorba*) is a perennial herb of the order Rosaceæ, sown occasionally with grasses on poor chalky soils in the drier districts of Great Britain.

It grows to a height of 18 to 24 inches, with an angular stem bearing pinnate leaves. The flowers are reddish green, without petals, and occur in dense, globular heads at the end of long peduncles. The fruit is quadrangular, with four entire wing-like margins. The portions between the wings are irregularly veined.

BURNET (*Continued*)—

In *P. muricatum*, the edges of the wings of the fruit are raised in little asperities. Seeds of burnet are frequently found as impurities in unmilled sainfoin, from which they differ by being smaller and quadrangular, and having irregular markings between their margins.

Burnet, when sown alone, is a coarse, unpalatable herbage, but when grown with grasses on dry soils, and in seasons of limited rainfall, it may have a limited value.

Before the introduction of most of the grasses now in general use, burnet was cultivated extensively, chiefly because of its hardiness and of its continued growth through the winter months, thereby providing a much-desired green foodstuff for cattle and sheep at a very lean time of the year. (See Seed Testing (Official).)

BUTTER—Butter is the substance produced by churning cream. It can also be made by churning milk or the fat separated from whey, in which latter case it is sold as whey butter.

In any case butter consists chiefly of milk fat (about 83 per cent.) with water (about 13 per cent.), the maximum limit allowed for water being 16 per cent. Salt butters contain about 2 per cent. of added salt, but in unsalted butters now specially in demand for the manufacture of "artificial" cream, no salt is added. Other milk constituents—proteins (0·6 per cent.), milk sugar (0·3 per cent.), and ash (0·14 per cent.)—though small in amount, are important in their influence on flavour and keeping qualities.

Considerable attention has been given to the nature of butter fat, and the researches of Hilditch (*Biochem. J.*, vol. xxiv., No. 4, pp. 1098-1113, 1930) give much information on the detailed analysis of butter fat, and the variations in the component fatty acids of butter due to changes in seasonal and feeding conditions.

Meigs, Blatherwick, and Cary (*J. Biol. Chem.*, xxxvii., 1, 1919) state that the fat of milk originates mainly, if not entirely, in the phospholipids of the blood. In butter the lecithin is present to the extent of 0·07 per cent. only, but may, through the nitrogenous base (choline) which it contains, be the source of fishy flavours. The development of these flavours may be accelerated by the presence of minute quantities of copper derived from the machinery used in manufacture.

A thesis on the subject of "The Fishy Flavour in Butter," by H. H. Sommer and B. J. Smit, is published in Research Bulletin 57, of the University of Wisconsin, October, 1923.

The vitamins A and D present in milk are associated with the fat, and are present in butter in proportion to that constituent (Crawford, Golding, Perry, and Zilva, "The Fat-Soluble Vitamins of Milk," *Biochem. J.*, vol. xxiv., pp. 682-691, 1930). The amounts present are largely dependent on the food of the cow (Golding, Soames, and Zilva, "The Influence of the Cow's Diet on the Fat-Soluble Vitamins of Winter Milk," *Biochem. J.*, vol. xx., No. 6, pp. 1306-1319, 1926).

A pound of butter supplies 3,410 calories, enough to support a man at moderately hard labour for twenty-four hours. It is, therefore, a very valuable food, and is 97·8 per cent. digestible.

J. G.

BUTTER (*Continued*)—

BUTTER MAKING—Butter making is practised in every country in the world, and though one would imagine that butter produced from milk would be the same wherever it is found, this is not the case. The cleanliness of the production of the milk, the methods adopted in the ripening and handling of the cream, the difference in the colour and size of the fat globules, all tend to alter the quality of the butter produced. The butter manufactured in England is mostly made on farms, and the quality is most variable, due to the lack of care and attention that should be given to the production and ripening of the cream. The management of the cream is most important, and it is advisable to use a culture or starter to bring about the proper souring or ripening. Immediately on separating, the cream should be pasteurized, cooled, and a starter added. This will regulate the production of the right acidity, and at the same time contribute to the flavour. The use of starters for ripening purposes is very general; they consist of mixed cultures, the type usually favoured being *Streptococcus lacticus*, *S. cremoris*, with small proportions *S. paracitrovorus*.

In countries such as Denmark, where dairying is such an important feature, milk is brought from the farm to the creamery, where it is pasteurized, separated, the cream ripened and churned daily; where a quick market is assured, a fairly high percentage of acidity is attained in the cream before churning. In other countries such as New Zealand, where the milk is produced over a very wide area, it is usually separated on the farm, and the cream sent to the factory, where, if necessary, the acidity is neutralized or standardized, previous to pasteurizing, ripening, or churning. The cream is churned with a low percentage of acidity developed.

In Ireland both ripening and non-ripening methods are followed, but here also pasteurizing the cream and cultures are used to attain uniformity. The actual methods of churning are the same wherever practised, and it is advisable to aim at a low churning temperature, or one that will not unduly interfere with the actual churning. This will produce a firm butter, which can be easily worked, thus getting rid of the water. A soft, oily butter is difficult to handle, usually contains a large proportion of water, and invariably has bad keeping properties. The salting of butter is important; when only a slight flavour of salt is desired, the butter should be brined, using $1\frac{1}{2}$ lbs. salt to the gallon of water before working. When a decidedly salt flavour is wished, dry salt is sprinkled on the butter on the worker, and partly worked in, then it should stand for at least three hours, for the salt to dissolve before finally working. Much of the butter made on the farms is streaky and discoloured, caused by working the butter too soon after salting. The packing is important, and whether put on the market in bulk or in packets it should be attractive. All utensils coming in contact with milk, cream, or butter should be thoroughly washed and sterilized after each time they are used.

A. T.

BUTYRIC—Related to butter; an adjective used chiefly in the combination "butyric fermentation," which refers to the process taking place when sugar or starch is fermented by means of decaying cheese in the presence of chalk. In this process "butyric acid," C_3H_7COOH, is often produced from the butyl alcohol formed. Butyl alcohol tends to appear also in ordinary yeast fermentation, butyric and acid can be clearly recognized by its smell in rancid butter.

BUTYROMETER—See Milk.

CABBAGE FAMILY—See Market Gardening; also Brassicæ.

CACAO—The cacao plant (*Theobroma cacao* L.) is native to the rain forests of tropical America, and it is this fact that conditions its range in cultivation and its culture. It is the most essentially tropical of all the major cultivated plants, and is only found under cultivation where the conditions of the rain forests can be approximately reproduced. Its culture is, therefore, confined strictly to the tropics and to low altitudes, in Ceylon reaching 2,000 ft. The tree is small, some 25 ft. in height, with spreading branches. The manner of branching is characteristic. The main stem ends abruptly at a height of 3 to 5 ft. in three to five spreading branches (jorquettes), while, from the main stem below these, a bud develops into a vertical shoot (chupon or watershoot) which, in its turn, terminates in a similar series of jorquettes. This method of growth may be repeated when the tree will be composed of a number of storeys. Equally characteristic is the manner in which the flowers are borne. These arise in clusters, reduced dichasial cymes, on cushions situated on the main stem and branches. Flowering may commence in the third year, but a crop yield will not be obtained till the fifth year, and full bearing will only be reached in some ten years.

The flowers are borne continuously and fruit yielded all the year round, but, in effect, there are definite crop seasons—in Trinidad a major and minor season in November to January and April to June respectively, and on the Gold Coast in September to January and May to June respectively. There appears to be a close correlation between the amount of the crop and the rainfall occurring in the fifth and sixth month preceding, a period which receives its explanation from the fact that it agrees with the period of development of the pod (Dunlop, *Trop. Agric.*, ii., 5, 1925; Skidmore, *Gold Coast Agric. Dept., Bull.* 16, 1928; Waters, *Gold Coast Agric. Dept., Bull.* 16, 1928).

There are three main varieties of cacao in cultivation, known respectively as Criollo, Forastero, and Calabacillo, here ranged in order of the quality of the product. They are distinguished mainly by the shape of the pod. Within these varieties there are an indefinite number of forms, and the normal cacao plantation is in no sense a pure culture. Though the plant is prolific of flowers, only some 5 per cent. of these receive pollen and only some 0·3 per cent. set, the pollinating agent appearing to be ants and aphides (Harland, *Trop. Agric.*, ii., 2, 1925; Stahel, *V. der K. Akad. van Wet. te Amsterdam, Af. Nat. Tweede Sect. Deel*, xxv., 6).

The plantation crop, which is normally raised from seedlings, is,

CACAO (*Continued*)—

under these conditions, a mixture of heterozygous forms. Within this mixture it is possible to determine trees characterized as good setters and others as shy setters (Harland, *Trop. Agric.*, ii., 4, 1925). At the River Estate, Trinidad, a determination from three years' observation gave (Freeman, *Trop. Agric.*, vi., 5, 1929) trees with—

Pods.	*Per Cent.*
0 to 12	23·0
13 to 25	20·0
26 to 50	30·4
51 to 75	15·9
76 to 100	6·0
Over 100	4·7

Yield could, therefore, be largely increased merely by replacing poor yielders, and it is a matter of importance to determine whether the heavy bearing character is transmissible. As would be anticipated, certain trees have been found to transmit this character, but it is only determinable by actual trial of second generation plants (Harland, *Proc. Agric. Soc. Trinidad*, xxviii., 1928; Williams, *Trop. Agric.*, vi., 2, 1929; Auchinleck, *Yearbook Gold Coast Dept. Agric.*, 1927). The process is lengthy, but it is clearly possible to raise a stock of high yielding plants. The cacao plant is readily propagated vegetatively by grafting or budding, and here again the capacity for high yield may, or may not, be transmitted to the vegetatively produced off-spring. It would appear that here there is involved a question of the stock, and before a high yielding clone can be established a suitable type for use as stock must be evolved (Harland, *Trop. Agric.*, i., 5, 1924; Van Hall, *Trop. Agric.*, vii., 1, 1930). The source of the buds is also a matter of importance, for the result will differ according as the source is a chupon or a jorquette (Harland, *Trop. Agric.*, i., 9, 1924).

Cultivation is dominated by the natural habitat of the tree, the tropical rain forests, and cultural effort is directed to the reproduction of the essential features of such a habitat. This is only possible where there is a secure rainfall, fairly well distributed with no severe dry period. The cacao plant is very susceptible to drought at the root, and a thick mulch of vegetable matter must be built up; such a mulch will conserve moisture, and, in the case of heavy clays, prevent root injury from cracking. Forking may prove advantageous, but must be done with caution. Though the plant can withstand a considerable degree of water-logging, this should be avoided by open drains between the rows. More recently a system has been evolved in Trinidad in which, on a five-year rotation, a drain, some 2 ft. wide and 18 ins. deep, is dug between each, or each alternate, row, and filled in with weedings, trimmings, and pen manure, the filled drain being then earthed over (Freeman, *Trop. Agric.*, vi., 5, 1929). The good results obtained are, no doubt, due to a combination of circumstances, of which the more important are probably the equalization of aeration and water supply in the soil.

As important as the maintenance of soil humidity is protection from wind. Where winds are frequent, windbreaks must be provided,

CACAO (*Continued*)—

and the plant is, further, commonly grown under shade. The commonest tree used for shade is the "immortelle" (*Erythrina umbrosa* and *E. velutina*), but other trees, usually of the N.O. *Leguminosæ*, are also used. The intensity of the shade is of importance (Freeman, *loc. cit.*). For the establishment of a plantation temporary cover is provided by the prior establishment of a crop, usually bananas, before planting out the cacao.

The plants are normally spaced so that the branches of the mature trees will intermingle, and the actual distance will naturally vary with the locality: 12 by 12 ft. and 16 by 16 ft. are distances commonly adopted. The effect of spacing on yield is a complex one, for a time factor is involved. For the first few years close planting gives the heavier yield, but later the reverse becomes the case, and it is a question of the economic balance between early and deferred return on the cost of management (Freeman, *loc. cit.*).

Pruning, which is commonly practised, has hardly yet been reduced to a scientific basis, though, as an art, it is a highly skilled process. Essentially it is a dual process, the control of the chupons, or water-shoots, to conform with the desired shape of tree and the trimming of the branches so as to secure a well-balanced tree. The latter process passes into cleaning, or the cutting out of any twigs showing signs of disease, and of epiphytic growths so common under these conditions.

The fruit is cut when fully ripe, and this, again, is a skilled process; firstly, to determine the degree of ripeness of a fruit at some distance from the ground is a matter of much practice, and, secondly, the act of severing the pod with a knife carried on a long pole without cutting into the bark or cushion, and thereby causing a wound, is by no means easy. The pods are collected into heaps, each is then cut in two with a heavy knife (machete), the pulp containing the seed scooped out into baskets, and the shells thrown in a heap to rot and to be subsequently returned to the land.

The pulp is conveyed to the "sweating" tanks, which may be concrete, wood, or even basket-work, receptacles, and, in the first case, a drainage aperture is provided. In these the pulp ferments with a rise of temperature to some 115° F. The process of fermentation lasts from two to four days, during which the pulp is turned several times to ensure even fermentation. From the tank a claret-coloured, vinegary liquid drains away while the seed undergoes the initial stages of germination. As carried out in practice, the process is empirical, and requires considerable skill in determining the time of completion. Detailed knowledge of the process is slight ("Fermentation of Cacao," 1912; Ashby, *Trop. Agric.*, ii., 5, 1925; Hardy, *Trop. Agric.*, iii., 11, 1926), but quality in the final product is to a large extent the result of the correct conduct of "sweating," though the varietal origin is not without its influence (Watts, *Trop. Agric.*, ii., 8, 1925).

The "beans," on completion of the "sweating" process, are dried by artificial heat, or, more commonly, spread on trays and exposed to the sun. Care must be taken that the drying process is not too

CACAO (*Continued*)—

rapid, and this, as well as protection from rain, is effected by a system of sliding roofs which can be drawn over the spread beans.

The conditions under which cacao is grown are ideal for many forms of parasitic life, and the pests from which the crop suffers are numerous. Among the more important are Black Pod-rot (*Phytophthera faberi* Maub.), which, besides attacking the pods, induces a canker; root diseases due to *Fomes* and certain other fungi; "witch-broom," induced by *Marasmius perniciosus* Stahel (*Dept. v. d. Landb. Suriname, Bull.* 33 and 39), responsible in the past for extensive damage in Surinam and recently found in Trinidad; and, among insects, the stem borer (*Steirastoma depressum* L.) (Van Hall, "Cocoa," chap. viii.).

The areas within the Empire in which cacao is produced are limited, though, owing to the rapid extension of cultivation in the Gold Coast in recent years, the Empire produces over one-half of the world's supplies.

Trinidad and Tobago—These two islands are the most important cacao-producing area in the West Indies, and produce some 25,000 tons annually of a quality ranking second only to the Ecuador product. A wide range of varieties is found in all plantations, but they are all of the Forastero type. The main producing areas are the hilly districts of the northern and central ranges of Trinidad. Wind-brakes are essential as protection against the trade winds which blow across the Islands, and the "immortelle" is almost universally used as shade. A yield of 2½ cwts. per acre may be accepted as an average yield. The crop is mainly produced on a plantation system, and much care is devoted to its culture. The low prices of recent years have, however, adversely affected the care expended, while the recent appearance of the Witch-Broom disease is giving cause for anxiety.

Grenada—The cause of the declining production, which now amounts to only some 3,000 tons per annum, is mainly economic. With high prices and a very limited area, cultivation was extended to land not really suitable for cacao cultivation. Grenada differs from the other West Indian Islands in that shade is generally omitted, except for the young plantation, when the banana is used as elsewhere.

Other West Indian Islands—Jamaica produces some 4,000 tons, and cacao forms a minor crop in several of the remaining islands. Cultivation differs in no material respect from that of Trinidad.

The Gold Coast—The history of the development of cacao in the Gold Coast forms one of the epics of tropical agriculture. An export trade, started in 1891 with 80 lbs., now amounts to some 225,000 tons. Only some 2,000 of the 900,000 acres are grown on a plantation basis, and it is this essential difference that is responsible for the peculiar problems which have arisen in the course of this rapid expansion. The unit of production is a plot of 1 to 10 acres; cultivation is of the most primitive nature, with little shade beyond that provided by nature. This lack of care in a crop, which now occupies extended areas, raises problems of disease which are difficult of solution. Preparation of the

CACAO (*Continued*)—

beans, too, is confined to the small lots of the individual producer, and fermentation is frequently conducted in an open heap. The prepared produce is, consequently, of low grade, and this, combined with the need for a collecting agency prepared to pay spot cash for the small lots, raises difficult problems of marketing (Auchenleck, *Gold Coast Dept. Agric., Bull.* 16, 1928).

Other African Colonies—Cacao is produced in the other West African colonies, particularly Nigeria with some 50,000 tons, under conditions similar to the Gold Coast.

Ceylon—Cacao has long been grown in Ceylon, but the area suited to the crop is limited. Originally Criollo cacao was grown, but latterly the more hardy Forastero type has been introduced. Production is on a plantation basis. Considerable care is taken over cultivation and preparation of the product, which, although now composed of Forastero as well as the "Old Red Ceylon," a Criollo type, is of the lighter colour of the latter and ranks high in the world's markets.

H. M. L.

CAFFEINE (1 : 3 : 7 tri-methyl purine) is identical with theine. It is found in coffee beans, tea leaves, cocoa, and kola, of each of which it is the active stimulating principle. The drug itself causes an increase in the basal metabolism of animals without increasing either the pulse rate or body temperature. It stimulates the respiratory centres and increases the respiration rate. Hypodermic injections of salts of caffeine are employed in combating the effects of narcotic poisons, such as veronal, etc.

CALCIUM—(Symbol Ca; atomic weight 40·07; atomic number 20). A soft silvery metal which tarnishes rapidly in air, and dissolves with some effervescence in water, producing lime. It occurs naturally in considerable quantities in combination as chalk, limestone, apatite, gypsum, animals' bones, etc., and it is only in combination that it is of importance (see Elements, Chemical).

The *oxide*, CaO (lime), is made by burning limestone or chalk, $CaCO_3$, in kilns, when the following reaction takes place: $CaCO_3 \rightleftharpoons CaO + CO_2$. (See Lime and Liming.)

Calcium carbonate, $CaCO_3$ (chalk), is frequently used on the land for the same purposes as lime, but it is slower in action. It is soluble to some extent in water containing CO_2, and the water thus becomes "hard." The hardness is temporary, and may be removed by boiling.

The *sulphate*, $CaSO_4$, appears as gypsum and plaster of Paris, which is the so-called "hemi-anhydrous" form ($CaSO_4$, $\frac{1}{2}H_2O$). The formula given is of course ridiculous, the truth being that the plaster consists of anhydrous $CaSO_4$ with some unchanged gypsum, $CaSO_4,2H_2O$, or monohydrate $CaSO_4,H_2O$. It is responsible for permanent hardness in water.

Calcium carbide, CaC_2, is now largely used for lighting and other purposes. (See Acetylene; Nitrogen, Fixation of Atmospheric.)

CALCIUM (*Continued*)—

The *sulphide*, CaS, and *polysulphides* are present in "lime sulphur," the insecticide and fungicide made by boiling lime and sulphur with water. (See Insecticides and Fungicides.)

The *phosphates* are dealt with under Superphosphate. (See Fertilizers.)

Bleaching powder, $CaOCl_2$, is an oxy-chloride of debated constitution which reacts with acids in much the same way as hypochlorites, giving off chlorine to which its bleaching action is indirectly due.

A calcium substituted casein known as *calcium caseinate* is used in horticulture to increase the penetrating and wetting power of sprays, etc., especially in dealing with Woolly Aphis.

The *arsenate* and *arsenite* are used for the destruction of Leaf Worm and Boll Weevil on cotton plants.

CALCIUM CYANAMIDE—See Fertilizers.

CALORIE—The unit of heat; the amount of heat required to raise the temperature of one gram of pure water one degree Centigrade (strictly from 0° to 1°). This is the gram calorie. There is also a larger calorie = 1,000 gram calories—that is to say, it is the amount of heat required to raise the temperature of one kilogram of pure water one degree Centigrade—the kilogram-calorie then. This calorie is, by a convention, written with a capital letter, but as the convention is by no means invariably observed, it would perhaps be better if they were always distinguished as gm.-cals. and kg.-cals.

CALORIMETER—An instrument for measuring *heat*, differing from a thermometer, which is used to measure *temperature*. The difference between these should be carefully noted: a small amount of heat will suffice to boil a small drop of water, *i.e.*, to increase its temperature considerably, while the *same* amount of heat would not appreciably change the temperature of a barrel of water. (See Calorimetry, Animal.)

CALORIMETRY, ANIMAL—The greatest discoveries are rarely the work of one man unaided by the approximations and half-truths formulated by his predecessors and contemporaries, and this is as true in regard to the demonstration of the applicability of the principle of the conservation of energy to the animal organism as in that of the great physical law itself.

Energy in the inanimate world of physics is defined as ability to do work, and is measured by the amount of mechanical work that there is ability to do, or by the equivalent of this in terms of heat at the rate of 4·18 joules of work to the calorie of heat. The same definition holds without alteration among living creatures, and the same law that it can neither be created nor destroyed by any process we are aware of. This is the fundamental fact on which the science of biocalorimetry has arisen, and on which its usefulness depends. Every particle of food eaten by an animal contains a definite amount of energy, and the products into which it is katabolized a lesser amount. The difference we can have either entirely in the form of heat energy or partly as heat and partly as fat, meat, milk, work, etc., but its

CALORIMETRY, ANIMAL (*Continued*)—

quantity is fixed, and whatever we do we can obtain neither more nor less than this fixed quantity from the transformation of the food into its ultimate katabolites.

In studying the requirements of animals under varying conditions there is thus one product of metabolism—heat—that it is difficult yet absolutely necessary to keep track of, and in this fact we find the *raison d'être* of the largely increased popularity of animal calorimeters and respiration chambers in agricultural science during late years.

Before proceeding to the fuller consideration of those instruments which are solely or mainly employed in agricultural work, it will not be amiss if we take a rapid survey of the development of this branch of science.

That there are two independent means of arriving at the heat given off was recognized long before the development of the doctrine of the conservation of energy, since heat was previously regarded as due to the presence of a more or less material, though "very subtil," fluid "caloric," which could enter into and be expelled from chemical compounds. Thus we find in the earliest attempts of Adair Crawford of Glasgow, in 1777, the embryo of the direct calorimetry of today, in which the heat itself is measured as such, and which found its further development in the apparatus of Dulong, Rubner, Atwater and Rosa, Noyons, etc., while the contemporaneous work of Lavoisier, Laplace, and Seguin gave us the indirect method, which depends *in essence* on the fact that if we know the proportion in which fats and carbohydrates are being burned in the body, and if we also know the heat of combustion of each separately, we can compute that of the combination. Lavoisier and his collaborators laid the foundation for the development of both the open and closed circuit types of respiration chambers. The former type, whose further development can be traced through the instruments of Pettenkofer, Voit, Tigerstedt, and Sondén, etc., to that of Møllgaard, which will be described shortly later, is so arranged that fresh air is constantly admitted to the chamber, and volume measurements and analyses of the gases passing out are made at regular intervals. The latter type, which led to the apparatus of Regnault and Reiset, Hoppe-Seyler, Zuntz, Krogh, Benedict,* and others, is, as its name implies, closed, and the CO_2 and H_2O which would otherwise accumulate in the closed volume of gas are chemically abstracted and their places supplied by fresh O_2.

While it is quite clear how the metabolism may be measured, given an instrument capable of registering the amount of heat evolved by the animal, since the two are identical when there is no heat storage or body cooling, which condition obtains in metabolism experiments as a rule, it is by no means so obvious how this figure is to be determined from observations of the gas exchange. Let us for a moment consider the equation for the complete oxidation of glucose:

$$C_6H_{12}O_6 + 6O_2 = 6H_2O + 6CO_2.$$

* That at Durham, New Hampshire, U.S.A., is of the Pettenkofer type.

CALORIMETRY, ANIMAL (*Continued*)—

Now, by Avogadro's law the molecular weight in grams of *any gas* under the same conditions of temperature and pressure occupies the same volume. Hence the weight of gas represented by $6CO_2$ in the equation will occupy the same volume as the $6O_2$ used to oxidize the glucose; that is, the volume of carbon dioxide produced will be equal to the volume of oxygen used. This is generally true of the oxidation of all carbohydrates, a general equation for which may be given thus:

$$C_x(H_2O)_y + xO_2 = yH_2O + xCO_2.$$

The ratio of the volume of CO_2 produced to that of O_2 used is $\frac{x}{x} = 1$. This ratio, in the case where the oxidation is performed by an animal, is called the *respiratory quotient*, and we see that where carbohydrate only is oxidized this figure is unity.

Fats contain more hydrogen in their molecule than is required to make up the elements of water with the oxygen present in the molecule, so that more oxygen is required to burn them than the carbon dioxide formed from the carbon in their structure. If we express the composition of fats by the general formula $C_x(H_2O)_yH_{4z}$, in which the coefficient 4 is only used for convenience in writing the equation, we have for the combustion of fats—

$$C_x(H_2O)_yH_{4z} + (x+z)O_2 = (y+2z)H_2O + xCO_2.$$

Here the respiratory quotient is clearly $\frac{x}{x+z} < 1$. In point of fact it is found that its value is *very nearly the same for all fats,* and the mean respiratory quotient for fat metabolism is taken as 0·707.

In the animal body, however, not only carbohydrates and fats but also proteins are katabolized, and this complicates matters. If only carbohydrates and fats were used, then if, *e.g.*, the respiratory quotient were half-way between 0·707 and unity, it would mean that of the total metabolism one-half was due to combustion of fat and one-half to combustion of carbohydrates. Before we can proceed in this way the protein must be taken into account. The respiratory quotient of protein varies appreciably more than does that of fat, but as the protein katabolism is not a very large proportion of the whole it has been found sufficiently accurate to take a mean of about 0·8 for the respiratory quotient of protein metabolism. In practice the amount of protein katabolized is reckoned to be proportional to the nitrogen in the urine; usually this is multiplied by the factor 6·25 to get the protein. To determine the non-protein respiratory quotient, *i.e.*, that due to the carbohydrate and fat combustions only, it is necessary to subtract from the actual volumes of oxygen used and carbon dioxide produced that part of each which is due to protein katabolism. For carnivora it is usual to subtract 4·754 litres CO_2 and 5·923 litres O_2 for every gram of nitrogen in the urine. In their work with steers Benedict and Ritzman use 4·837 and 5·982 litres* respectively. This procedure, it should be noted, makes two important assumptions: (i) that no

* Computed from table 53, "Undernutrition in Steers," p. 201.

CALORIMETRY, ANIMAL (*Continued*)—

substances but carbohydrates, fats, and proteins are katabolized, and (ii) that there is no synthesis. Given this, the ratio of the remaining CO_2 to the remaining O_2 is the non-protein respiratory quotient $= \Omega$ (say). Hence, of the oxygen remaining after this deduction—

$100\frac{1-\Omega}{1-0\cdot707}$ per cent. has been used for combustion of fat; and

$100\frac{\Omega-0\cdot707}{1-0\cdot707}$ per cent. has been used for combustion of carbohydrate.

We now have all the data necessary to compute the heat production, since we know the amounts of oxygen used in the combustion of fat, carbohydrate, and protein respectively, and it is also known that—

1 litre of O_2 used in burning fat generates 4·686 Calories of heat.*

1 litre of O_2 used in burning carbohydrate generates 5·047 Calories of heat.*

1 litre of O_2 used in burning protein generates 4·60 Calories of heat.*

The difficulty often experienced in understanding this method arises from the inversion of the ordinary mental attitude which is demanded. We are accustomed to consider the burning of a combustible body by oxygen, but here we must rather dwell on the equally correct notion of the burning of oxygen by a combustible body.

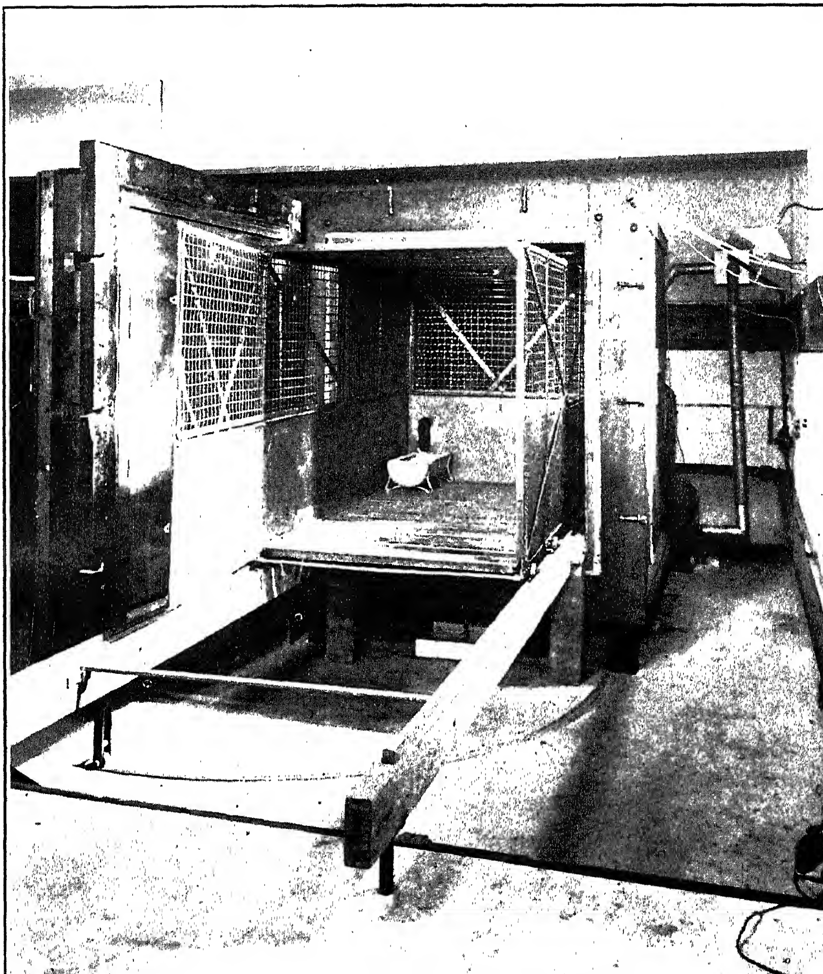
The use of the indirect method demands much care, as abnormal respiratory quotients are very frequent. The respiratory quotient is raised by the formation of fat from carbohydrates, which liberates oxygen, thus lessening the amount apparently absorbed, also by the formation of carbon dioxide, by fermentative changes in the gut. On the other hand, it is lowered by certain pathological conditions, as diabetes, myxœdema, etc., by the formation of carbohydrates from fat as in hibernating animals and by the incomplete oxidations due to acidosis.

When a small positive carbon balance is known to exist in a maintenance experiment by this method, a correction may be applied by increasing the observed amount of oxygen absorbed by the amount computed to correspond to the fat storage, if there is reason to believe that this is derived from carbohydrates, as is usually the case. When both carbon and nitrogen balances are positive, *i.e.*, when protein is also being stored, the correction is far less certain. The process of protein storage has probably little or no effect *per se* on the respiratory quotient, but secondary effects of a specific dynamic nature on the metabolism as a whole are not excluded. Probably the best way is to make the nitrogen balance as true as may be, and then correct the carbon balance by the carbon of protein synthesis before making the correction for fat storage.

Indirect calorimetry has, nevertheless, many advantages, especially with animals of small size, and is in any case usually quicker than direct heat measurement and better adapted to the determination of a rapidly varying metabolism, and hence it has commended itself to a large majority of workers.

* Figures from Lusk, "Science of Nutrition," 4th ed., 1928, pp. 65 and 68.

PLATE VII



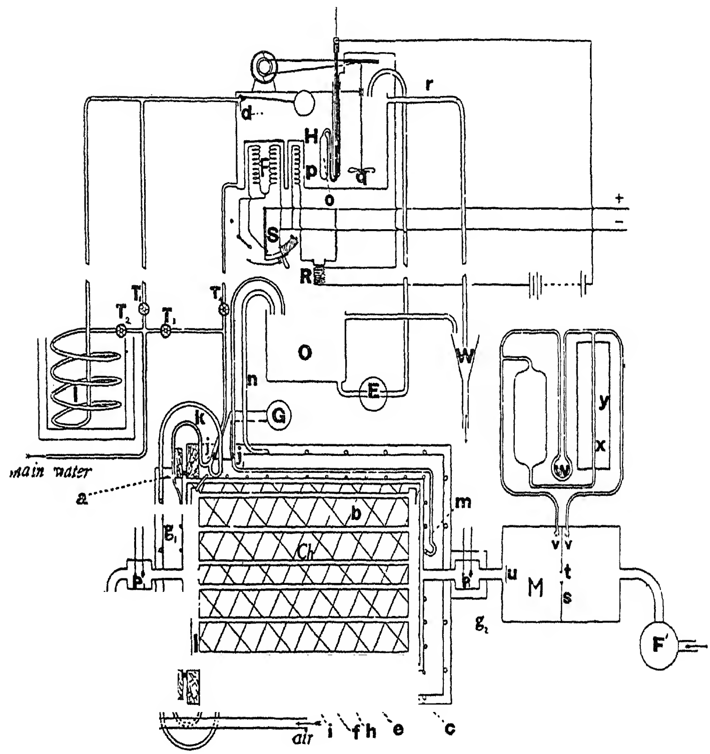
VIEW OF LARGE ANIMAL CALORIMETER, SCHOOL OF AGRICULTURE, CAMBRIDGE UNIVERSITY

The instrument is seen open for the admission of an animal. The cage (Ch in Plate VIII.) is partly run out on to a movable bridge, carrying a wooden floor with it, at the far end of which is a water trough, which can be filled from outside without opening the calorimeter when the cage is pushed back into place. When the animal is put in and the cage pushed back the bridge can be taken away in sections and the door closed and bolted. Immediately beneath the front is shown the tray for collection of urine.

(By kind permission of the Director of the Institute of Animal Nutrition, School of Agriculture, Cambridge.)

To face p. 210

PLATE VIII



DIAGRAMMATIC SCHEME OF ONE OF THE ANIMAL CALORIMETERS AT THE INSTITUTE OF ANIMAL NUTRITION, CAMBRIDGE UNIVERSITY.

To follow Plate VII.

CALORIMETRY, ANIMAL (*Continued*)—

Space does not allow of any fuller discussion of the history of the subject in general. As might be expected, most of the instruments which have been built have been intended and used for work with human beings. For any whose interest may lead them to wish to follow the matter in other than agricultural directions, it may be said that a very useful technical description of the majority of historical instruments up to 1911 is to be found in a long survey in Tigerstedt's "Handbuch d. Physiologischen Methodik," Bd. I., Abt. iii., pp. 71-228, the part dealing with respiration work by R. Tigerstedt, that on direct calorimetry by Max Rubner. This may be brought up to the present time with the aid of the numerous articles by present-day workers in Abderhalden's "Handbuch d. Biologischen Arbeitsmethoden," Abt. iv., Teil 10.*

Here we shall consider only those modern instruments which are used exclusively or largely for work with farm animals. These are still far from numerous, comprising: (i) The two Cambridge calorimeters, of one of which plates are given; (ii) the respiration-calorimeter at the Pennsylvania State College, in charge of Professor E. B. Forbes (these are both for direct calorimetry, the latter being also available for gas-exchange work); (iii) the respiration chamber at the New Hampshire Experimental Station, Durham, New Hampshire, in charge of Professor E. G. Ritzman, most of whose work is published in collaboration with Professor F. G. Benedict of the Nutrition Laboratory, Boston, Mass.; (iv) the respiration chamber of the Dyrfysiologiske Laboratorium of Kgl. Veterinær og Landbohøiskole, Copenhagen, directed by Professor H. Møllgaard. There are also a number of respiration chambers in process of construction at the Landwirtschaftliche-Versuchsstation, Möckern, Leipzig, at the laboratory of Professor Fingerling, which are not yet complete, and a direct instrument designed by Professors J. Lefèvre and A. Auguet at the Institut des Recherches agronomiques, 16, Rue de l'Estrapade, Odéon, Paris, of which a description in detail is published in *Annales de Physiologie et de Physico-Chimie Biologique,* T. v., No. 2, pp. 318-348 (1929).

In Plate VIII is shown in diagrammatic and somewhat simplified form the scheme on which one of the Cambridge instruments is built. The animal is placed in a chamber Ch, and the door D closed tightly with heavy bolts (not shown) so as to form an air-tight seal against the rubber gaskets *a a*. The animal is surrounded by a cage *b*, to prevent its lying against the side of the metal enclosure *c*. The heat eliminated is estimated as the sum of four factors: (i) that absorbed in a stream of water circulating in lead pipes soldered on to the outside of the enclosure *c*; (ii) that used in heating the air supplied for ventilation; (iii) that used to evaporate moisture, rendering the outgoing air wetter than that which enters; and (iv) a small amount which leaks

* Owing to the large number of volumes as ordinarily understood comprised in this work it is not often found complete; the part cited is in the library of the School of Agriculture, Cambridge University. There is, unfortunately, nothing in English, as far as I am aware, that supplies this information.

CALORIMETRY, ANIMAL (*Continued*)—

out through the insulation. Water enters the apparatus from the mains where shown, and passes to the taps T_1, T_2, T_3, T_4. With T_1 alone open, the water passes direct to the ball cock *d* in the tank H. With T_2 alone open, it reaches the same destination by way of the cooling coil in the ice tank I. In either case the opening of T_4 allows water to pass from H to the circulating pipes of the calorimeter. These are in two sets: an inner *e*, on the outside of the metal enclosure *c* which is separated from another metal casing *f*, by about 6 ins. of compressed cork insulating material *g*; and an outer *h*, on the outside of *f*, covered with a light insulation *i*, in a wooden casing. The function of the outer circulating pipes is to maintain the outside of the insulation *g* at approximately the temperature of the interior, and to this end the water from T_4, after passing a thermojunction at *j*, is divided into two streams, one serving the inner, the other the outer circulation; the former stream passes to the inner plate of the door by an insulated pipe *k*, to a special heat absorber *l*, in the ceiling of the chamber Ch, and to the inner circulation pipes *e*, finally flowing by the pipe *m* over the thermojunction j_1 to the outflow tank O, where it can be measured, and eventually to the waste pipe W. The outer water stream, turning by the outer branch at *j*, runs over the outer plate of the door, which is separated from the inner by the insulation g_1 to the outer pipes *h*, and eventually by *n* to the tank O. The water in H is kept at a constant temperature by a thermostat control *o*, working through a relay R, on the regulating heater *p*. Extra constant heating may be supplied as required by the heaters F, which may be used singly, in parallel, or in series by the switch S. The tank H is provided with a stirrer *q*, and an overflow pipe *r*, running to the waste pipe W. From the tank O a pipe runs to a return pump E, which serves to send back the already warm water in O to H, thus saving considerably on heating current in winter. The temperature difference between the inlet and outlet water of the inner circulation is found from the registration of the galvanometer G, in connection with thermojunctions jj_1. By opening T_3 after closing T_4, it is clear that the main pressure may be used to flush thoroughly the pipes of inner and outer circulation.

Air for ventilation is drawn through the chamber by the exhaust fan F′. It enters by the pipe indicated by an arrow, which may, if desired, be cooled with ice, and passes to the chamber by the inlet psychrometer P_1 and out again over the outlet psychrometer P_2 which is insulated with compressed cork g_2; thus the temperature and humidity of the air are determined on entry and exit, and from these the two next factors in the heat elimination are computed, *i.e.*, the heat taken out by the air stream and the heat removed as latent heat of vaporization of water. For this the air flow must be known, and this is measured in the box M, divided into two parts by a stainless steel plate *s*, with a hole *t*, in the centre. When the fan F′ is running the pressure on the fan side of *s* is less than that on the calorimeter side of *s*, and from this pressure difference the flow through *t* may be computed; a baffle is introduced at *u* to help to prevent the

CALORIMETRY, ANIMAL (*Continued*)—

stream lines in the boxes assuming a form in which the formula does not apply, and the ends of the manometer tubes v_1 v_2 are protected with gauze to avoid possible eddy effects. The manometer w is of the ordinary type, while there is also a differential manometer x, in a light-tight box y, whereby variations in the pressure difference may be photographically recorded. The leakage of heat through the walls is determined from a series of blank experiments.

The respiration calorimeter at the Pennsylvania State College, originally designed and built by Armsby on the plan of the Atwater-Rosa instrument, consists of two shells, the outer of zinc, the inner of copper. Heat exchange between these two is prevented by having 600 thermojunctions placed between them all over the surface; thus if the mean internal temperature becomes greater than the mean external temperature, or *vice versa*, a current will flow in one direction or other in the thermoelectric circuit, and compensation can be made accordingly by heating resistance nets or water cooling, with both of which the outer zinc enclosure is furnished. This adjustment is made by hand, it being assumed that the small errors in either direction will cancel out over a long experiment. The instrument is thus adiabatic, and heat insulation is dispensed with.

Heat generated inside is taken out by heat-absorbing pipes in the ceiling, the thermometers, reading to $\frac{1}{50}$° C., at inlet and outlet of these absorbers being read every four minutes. The absorbers may be weighed from time to time from outside to keep check of condensation on them. The internal temperature of the chamber is kept approximately constant by varying the water stream or by altering the rate of absorption by means of baffles below the absorption tubes. Air for ventilation is taken in over the expansion coils of an ice machine to dry it. A specially designed pump, consisting essentially of two cylinders reciprocating in mercury, is used to ventilate the chamber and at the same time to measure the air. Automatic sampling of the gases at the exit is provided by means of a shunt valve. Sulphuric acid and soda lime are used for absorbing H_2O and CO_2, and methane (CH_4) is determined by burning on platinized china clay. A chamber with air-lock in thermal communication with the main chamber is provided for the reception and removal of urine and fæces. The instrument is of the open-circuit type.

The apparatus at the New Hampshire Experimental Station consists of an air-tight respiration chamber, the floor of which is attached to a pneumograph operating on a revolving drum, by which every movement of an animal is recorded, and some estimate of its magnitude rendered possible; thus differences in this respect can be allowed for in the results. The chamber is provided with a sloping floor to enable urine to run off to a container, and nothing further is needed in short experiments; but in twenty-four-hour tests a rubber urine funnel is employed. The chamber is made of as small a volume as possible, consistent with its housing a 1,000-lb. steer; in this way the accuracy is improved as the volume of residual air is less. The apparatus is designed on the open-circuit principle of Pettenkofer, 10 per cent. of

CALORIMETRY, ANIMAL (*Continued*)—

the outgoing gases being aliquoted off for analysis. Sulphuric acid and soda lime are used as absorbents, two systems being arranged in parallel with a deflecting stopcock for convenience in running consecutive experiments.

The Copenhagen respiration chamber is of somewhat larger size than the above, and gas exchange can be limited to a smaller antechamber at the forward end. This is used for testing and when pulmonary exchange alone is investigated. Samples of the air of the main chamber are taken before and after the experiments, which are not usually of long duration. The apparatus is built on beams above a cellar which accommodates apparatus for dealing with the excreta, etc. Experiments are made both with and without tracheal fistulæ, for which proper conveniences are provided in the chamber, as also an arrangement whereby the animal may be milked when inside without the need for opening any doors. The interior temperature is regulable by water circulating in pipes on the sides. Ventilation is provided by two large mercury pumps of special design with coupled sampling pumps; but very much the same in principle as those at the Pennsylvania State College. The outgoing air is saturated with water vapour in a cinder tower before measurement, and the portions delivered by the sampling pumps, after measurement in constant temperature gas-meters, are analysed for CO_2 and residual O_2 instead of H_2O. Thus the respiratory quotient and thence the heat production can be obtained by the use of suitable factors in combination with the volume of O_2 used. Combustible products of metabolism are burned on a white-hot platinum spiral. Again, the open-circuit principle is employed.

It is noteworthy that in no instrument devoted to agricultural work is the closed circuit, or Regnault-Reiset, principle employed; while in work with human beings it is the rule rather than the exception. It seems probable that the considerations which have weighed with the designers in this matter have been mainly those of securing apparatus of the size desired and of requisite strength, which shall be sufficiently air-tight to operate spirometers satisfactorily, and, no doubt, the difficulty in purifying such large volumes of gas as are used with animals of large size. In the Paris instrument only one-fifth of the gas is purified, an equilibrium value being attained in a short time.

So much for the instruments with which researches on energy exchanges in the animal body, more especially the bodies of farm animals, are conducted. We must now turn to a brief consideration of some of the results that have been attained by this method of approach.

It was with the instrument at the Pennsylvania State College that the pioneer workers, Armsby and Fries, first established the now well-known theory of nett energy values in cattle feeding on the firm basis on which it has rested for the past fifteen years. If some of us are "hedging" a little on some of their cut-and-dried statements in the theory of the matter, there is, I believe, none who does not accept the main principle involved—namely, that the *whole* of the computed

CALORIMETRY, ANIMAL (*Continued*)—

metabolizable energy is *not* available for production, and when suitable changes are made the system of nett energy values assimilates itself very closely to that of starch equivalents (*q.v.*) introduced earlier by Kellner, which is in more common use in Europe. The reason why this has not been replaced by the newer, and scientifically more satisfying, system of Armsby and Fries is to be sought doubtless in the fact that the latter has the appearance of telling one far more than it actually does, and consequently disappointment is met with in its application; in this the drawbacks of Kellner's system are themselves forgotten. E. T. Halnan, writing in 1915 in a rather different connection (*J. Agric. Sci.*, vii, 174), said: "The beauty of the Kellner system lies in the fact that it gives the comparative values and not the absolute values of feeding stuffs for fattening purposes. . . . The farmer desires to know not how much fat or milk or work a food will produce, but rather which of several foods is more economical for any purpose he has in view." From the point of view of the agricultural scientist, however, there can never be any hesitation in preferring a system which rests on an energy basis to any which deals merely with comparative values; he knows from a hundred examples in physics, chemistry, etc., that the former path leads eventually to progress, the latter to stagnation, and is prepared to face the difficulties.

The constancy of nett energy values has been questioned recently by both Forbes (*J. Agric. Res.*, xxxvii., 253, 1928) and the present writer (*J. Agric. Sci.*, xix., 172 *et seq.*, 1929), in each case as the result of experiments carried out under submaintenance conditions. The former seems to think that the energy of body tissues katabolized in fasting should be separable theoretically into thermic and dynamic portions, and that it is this that causes a variation of the linear relation between food energy supplied and body nutrients saved in the Armsby-Fries procedure. It is not clear how the numerical relations of this can be established except from the experimental results which give rise to the theory, *i.e.*, by a *circulus in probando*, a difficulty which seems to be perceived by Forbes himself (*loc. cit.*, p. 286). Failing this, it would appear that dynamic (nett) energy and thermic energy of body substance katabolized in fasting are terms without meaning, since the *whole* of the heat elimination in fasting may be regarded as "nett" if we consider it as representing the heat value of this body substance, or as "thermic" if we consider that it all appears as heat when the animal is at rest. The writer has suggested that the results attained in his own experiments would find complete explanation if the nett energy value be regarded as a *statistical* rather than a *physiological* constant. (See Nett Energy Values.)

Further experiments at Cambridge seem to indicate that there *may* be some difference in metabolism according to breed; further work on this point is at present in hand, but owing to unforeseen complications the results are not likely to appear for some time. The chief result which has so far accrued from work with the Cambridge instruments is the establishment of the temperature coefficient of fasting katabolism at temperatures below critical. Much of the evidence

CALORIMETRY, ANIMAL (*Continued*)—

on which this statement is based is so far not published, though the first essay in this direction was published by Capstick and Wood in 1922 (*J. Agric. Sci.*, xii., 257) from observations on a single pig. It was stated by the present writer in the *Pig Breeders' Annual*, p. 51, 1928-9, that if the maintenance ration without exercise at 62° F. be M calories of nett energy, then the ration in pounds of food at (62° − t°) F. will not differ from that at 62° F., provided that $\frac{(100+3t)M}{100}$ is less than the metabolizable energy contained in the ration, and that in the contrary case the ration must be increased to such an extent as to make its metabolizable energy equal to $\frac{(100+3t)M}{100}$ Calories. Later experiments on a number more pigs appear to confirm these figures as a fair average for general use.

In the matter of milk production the results obtained by Møllgaard at Copenhagen are of vital importance. His experiments, which are still in progress, go to show that the nett energy value of a food for milk production must be measured by how much an exactly measured addition of food increases the positive energy balance of an adult animal whose protein requirement for maintenance is covered in the maintenance part of the ration, and which is well nourished at the beginning of the experiment—a result which in itself explains to the thoughtful reader the slowness with which any positive information may be won in this field, as also the importance of fundamental work for the correct interpretation of the results of feeding experiments.

Benedict and Ritzman, at Durham, N.H., have devoted themselves for many years past to the determination of the metabolism of the steer. Their results show, singularly enough, that there appears to be no temperature coefficient of fasting katabolism with these beasts, at all events within the temperature range over which they worked, and moreover that the basal metabolism per unit surface area is considerably greater (*ca.* 20 per cent.) than that of most animals. In experiments on under-nutrition they have found that when steers on low rations are suddenly given more food, so that their life processes are speeded up, these seem to swing beyond the normal, so that the animals can, as one might say, make up for lost time, which seems to contain a suggestion for tiding the farmer over a time of scarcity.

The future in this line will certainly be for some time a repetition of the past: slow progress, with results which require continuous modification, but which become more and more of direct use to the stock-feeder as they become crystallized into a simple and established form. It seems probable that greater progress will be made in the agricultural sphere where instruments of both kinds, or combined instruments, are available, as the direct instrument seems to possess considerable advantage for determining the heat elimination in fasting with precision, while it is nearly useless for excitable animals such as sheep and lambs, or where the metabolism changes rapidly.

T. D.

CANADA—Agriculture of—See Agriculture.

CAPILLARY—Any narrow tube or confined space of small diameter, such as the interstices of soils, the wicks of oil lamps, or the finest bloodvessels of the body. They are of importance for two reasons—firstly, water and liquids are sucked up into them, if they are already moist, and, secondly, owing to the large adsorption surfaces they afford, the course of chemical reactions is, under many circumstances, modified by them. In a work of this kind it is impossible to do more than touch on a few interesting facts in connection with the first of these; the second will be found fully treated in H. Freundlich, "Colloid and Capillary Chemistry," tr. H. S. Hatfield, London (Methuen), 1926.

If a narrow glass tube of internal diameter d cms. which is wet inside is dipped into water, the water will rise within it to a height $=\frac{\cdot 3}{d}$ cms.; it is therefore clear that if d is small the height to which the water is raised may be considerable. It was once thought to explain the ascent of sap in trees and of water in soils by this means alone, but to do this in the case of *Sequoia gigantea* would require the vessels to have a diameter $\frac{1}{5000}$ part of a millimetre, whereas in fact they are much larger than this; moreover, it is quite incapable of accounting for exudation of water at more than 100 drops a minute from the stomata of a leaf of *Colocasia nymphæfolia*. Even with root or osmotic pressure taken into account it fails, since the pressure in the vessels when the plant is actively transpiring is less than atmospheric. The ascent of sap, therefore, is generally allowed to be a vital phenomenon of some kind.

In soils (*q.v.*) the theoretical physical phenomena are more nearly shown, especially when the soil is sandy, but even there the deviation from theory is so great as to make it almost useless in dealing with problems of soil moisture. As far as it goes the matter is treated by Mitscherlich ("Bodenkunde," 4te aufl., pp. 118 *et seq.*), and was the subject of a careful and thorough analysis by King and Slichter (*Bull. U.S. Geol. Surv.*, 1892).

CARAWAY (*Carum Carvi*)—The seeds of the caraway plant are used in considerable quantities by the confectionery, drug, and other trades, and consequently it figures amongst the crop plants of most of the countries in the temperate zone. In Great Britain it is grown in Essex, Kent, and other seed-growing districts where the climate of the late summer can be depended upon for the work of harvesting the crop.

Caraway is a biennial, and must be sown on the land where the crop is to stand until it matures during the July or August of the following year. The crop prefers a light, warm loam on which a good surface tilth can be kept.

The seed should be drilled in rows 10 ins. apart; April being a good month for sowing. The plants are singled to about 8 ins. apart when about 2 ins. high. When the seed is ripe, the crop is cut and stacked, and later the seed is threshed out, cleaned, and marketed.

CARBOHYDRATES—A class of chemical compounds, including the sugars, starches, etc., conforming to the general formula $C_m(H_2O)_n$. They are divided into monosaccharides, disaccharides, and polysaccharides, according to the number of simple sugar (monosaccharide) molecules which are linked up in their molecules.

Monosaccharides are classed as tri-tetra-pent-hexoses, etc., according to the number of carbon atoms they contain, and are moreover divided into aldose and ketose sugars, according as the group which is chiefly active is an aldehyde or ketone group, *e.g.*:

$$\begin{array}{ccc} \begin{array}{l} CHO \\ | \\ (CHOH)_4 \\ | \\ CH_2OH \end{array} & \qquad & \begin{array}{l} CH_2OH \\ | \\ CO \\ | \\ (CHOH)_3 \\ | \\ CH_2OH \end{array} \\ \text{An aldose.} & & \text{A ketose.} \end{array}$$

The aldoses give most of the usual chemical tests for aldehydes, *i.e.*, they reduce warm dilute solutions, salts of gold and silver, reduce Fehling's solution (alkaline copper hydroxide), and yield osazones with phenyl hydrazine. Ketoses yield highly coloured phenyl methyl osazones with phenyl-methyl hydrazine; aldoses do not. Monosaccharides in general give a violet colour at the liquid junction if concentrated sulphuric acid is run to the bottom of a tube containing a mixture of a solution of the monosaccharide with a drop or two of α-naphthol. The fumes given off when a solid monosaccharide is heated in the dry state turn aniline acetate paper red. For details on all the foregoing matters see any good textbook of organic chemistry.

The differences between the various sugars are largely a matter of stereo-chemistry. Since all the carbon atoms of sugars, except the two end ones of the carbon chain, are asymmetric, it follows that the number of possible stereo-isomers is very large, and in the aldohexoses each of these is known and forms a different sugar, *e.g.*, the structural formula of glucose (dextrose) is:

$$\begin{array}{ccc} \begin{array}{c} CHO \\ | \\ H.C.OH \\ \\ HO.C.H \\ | \\ H.C.OH \\ | \\ H.C.OH \\ | \\ CH_2OH \end{array} & \text{while that of galactose is} & \begin{array}{c} CHO \\ | \\ H.C.OH \\ \\ HO.C.H \\ | \\ HO.C.H \\ | \\ H.C.OH \\ | \\ CH_2OH \end{array} \end{array}$$

Within recent years it has been found that two forms of glucose can be prepared differing from one another in their physical properties, the difference between them depending on the fact that the carbon chain is really bent round in an unclosed ring, so that the hydrogen of the hydroxyl group of the penultimate carbon atom can function

CARBOHYDRATES (*Continued*)—

as a hydrogen of the aldehyde carbon, making possible two isomers, called respectively α-glucose and β-glucose.

The only other monosaccharide of importance to the agricultural scientist is fructose (lævulose), which is a ketose of formula $CH_2OH.CO.(CHOH)_3CH_2OH$.

By an effect analogous to that just mentioned in connection with glucose, an α and β isomer are produced. For further details on these matters the reader may consult W. H. Haworth, "The Constitution of Sugars," London, 1928.

Glucose is found almost universally in the juices of plants and the blood of animals, while fructose occurs in honey and many fruits. Pentoses occur in many gums, resins, and pectin substances, while if glucosides be taken into account the natural occurrence of these bodies may be considered wider still. Glucose is said to be chiefly connected with respiration, fructose with tissue formation.

The disaccharide molecules consist of two monosaccharide molecules united together with elimination of the elements of water; *e.g.*, the commonest disaccharide sucrose (cane sugar) is formed from a molecule of glucose, and a molecule of fructose with elimination of one molecule of water.

Other disaccharides of importance are lactose (milk sugar), found in the milk of animals in varying quantity, and obtainable from evaporated whey, also maltose, produced by the action of diastase on starch in the malting of barley. Both these latter consist of a molecule of glucose united to a molecule of another sugar with elimination of water. Lactose is glucose β-galactoside, while maltose is glucose α-glucoside. The disaccharide glucose β-glucoside is interesting. It is called cellobiose, and was discovered by Pringsheim (*Zeitschr. f. physiol. chem.*, lxxviii., 266, 1912) as a product of the destructive fermentation of cellulose.

Raffinose, a sugar extracted from cotton-seed meal, is a trisaccharide. Beet sugar is, of course, identical with cane sugar in chemical composition.

There is one property of soluble sugars which must be touched upon in view of its importance in estimation—namely, their action upon polarized light. When a beam of light passes from the air into Iceland spar, it is split into two beams, which differ from one another in that the plane in which the light vibrations occur is exactly at right angles in one to what it is in the other. If one of these beams is totally reflected within the block of spar and absorbed on a dead black surface, the remaining beam passes through alone, and its vibrations occur in one plane only. The means by which this is accomplished need not be more nearly specified here; the resultant piece of apparatus is called a Nicol prism. If, now, a second Nicol prism be placed in the path of the emergent ray, a position may be found in which the light passes through perfectly, but on rotating the second prism through 90° none of the light from the first prism will pass through, since it strikes the second one in such a way as to be totally reflected and absorbed. Suppose now that a tube containing a sugar solution is interpolated

CARBOHYDRATES (*Continued*)—

between the prisms, light will again pass through the second prism, since the plane in which the light emerging from the first prism vibrates has been turned through an angle which depends upon the kind of sugar present, concentration, etc. This angle may be measured on an alidade fixed to the second prism, and the complete apparatus is known as a polarimeter or, when specially adapted for work with sugars, a "saccharimeter."

Sucrose is taken as the standard of sweetness; glucose and maltose are about one-half and lactose one-quarter as sweet as cane sugar, other things being equal, while fructose is about 25 per cent. sweeter.

Among the polysaccharides are many substances of the highest importance in agriculture; cellulose, hemicelluloses, lignin, starch, galactans, inulin, dextrin, glycogen, pentosans, and gums all fall within this class.

Cellulose is now known to consist of a large number of glucose groups joined up together, the exact mode and arrangement of the simpler molecules in that of cellulose being unknown. It is certain, however, that only glucose groups are concerned, since it may be quantitatively hydrolysed, and the conclusion is supported by the results of an X-ray analysis of its structure. It forms the chief constituent of the fibrous tissues of plants. It is peculiarly resistant to all ordinary chemical reagents, but singularly enough appears to be soluble in a strong ammoniacal solution of copper hydroxide. In both plants and animals it is broken down in large quantities by cytohydrolytic ferments, but H. E. Woodman (*J. Agric. Sci.*, xvii., 333, 1927, and xviii., 713, 1928), who fully confirmed the results of Pringsheim previously mentioned, points out that as far as laboratory experiments have so far determined the conditions under which such action can take place, it is not, in itself, capable of accounting for the great nutritive value of such substances to ruminants; but considers that his experiments afford some evidence that glucose may be the form in which cellulose is finally assimilated by the ruminant organism.

Hemicelluloses consist of hexose and pentose groups joined up, are more easily hydrolysed than cellulose, and are said to provide reserve material in plants. In conventional analyses they appear partly in the crude fibre and partly in the nitrogen-free extract. The lignins are aggregates in which some of the sugar groups have undergone methoxy- and ethoxy-substitution.

Starch is a polysaccharide of equal or even greater importance than cellulose. It is formed in the leaves of green plants under the influence of light, and is stored in the seeds and in tubers in large quantities. The form of the granules in which the starch is deposited is characteristic of the plant. Chemically it corresponds to the empirical formula $(C_6H_{10}O_5)_n$, and is easily hydrolyzed by dilute acids and alkalies, the final product of hydrolysis being glucose; it is broken down to glucose eventually by the digestive enzymes in the animal body. This process is begun in the mouth, where the ptyalin of the saliva breaks it down to dextrins and maltose, a process which is continued in the stomach and completed by the amylopsin secreted

CARBOHYDRATES (*Continued*)—

by the pancreas into the duodenum. The final hydrolysis of the maltose to glucose takes place in the small intestine. The dextrines are intermediate gum-like products obtained by partial breakdown of starch. Starch may be detected in very minute quantities by the intense blue colour due to the so-called "iodide of starch" which is produced in the presence of free iodine.

Animal starch or glycogen is a carbohydrate storage material found in the liver and other tissues of animals. It appears to serve as a ready source of energy, being depleted very easily by muscular work and starvation. Nothing less than tetanus, however, is required to secure the complete elimination of this substance, so that it probably has other uses. It gives a red colour with iodine.

Inulin is a starch-like substance found in considerable quantities in plants of the order Compositæ. It gives a yellow colour with iodine, and is built up of fructose units only.

Space does not allow of more than a passing mention of the other polysaccharides referred to. Galactans are composed largely of galactose units, and are found in leguminous plants. Pentosans are found in wood gums, and as pectins in fruits and root crops; and, as their name implies, consist of pentose sugar groups, which they yield on hydrolysis. The gums generally partake of the character of both of these latter types of polysaccharide.

CARBOLIC—A coal-tar product consisting in the pure state of phenol, C_6H_5OH. It is used in dyeing and the manufacture of explosives. It is an excellent disinfectant, and in dilute solutions acts to some extent as a local anæsthetic. Its tri-nitro-derivative, picric acid, is now largely used as a substitute for carron oil in the treatment of burns and some skin diseases. It is a violent irritant poison for which no efficient antidote is known; Epsom salts and Glauber's salts have been given, but are nearly useless. The only hopeful treatment is that of the stomach pump, followed by injections of caffeine or strychnine. Phenol gives a violet colour with a solution of ferric chloride.

CARBON (Symbol C; atomic weight 12·00; atomic number 6) occurs free in nature as diamond and graphite, and appears in commerce in more or less impure forms as charcoal, coke, coal, gas-carbon, soot, etc. The latter is useful for getting rid of snails and slugs in gardens in a small way. (See Soot.)

Its chief interest for the farmer is the fact that in combination with hydrogen, oxygen, and, often, nitrogen, it forms one of the chief constituents of the bodies of plants and animals. All organic substances without exception contain it in appreciable quantity. (See Elements, Chemical; Assimilation; Charcoal.)

CARBON DISULPHIDE (CS_2)—A heavy, mobile liquid with, as usually sold, a very unpleasant fœtid smell. It is said that when quite pure its odour is ethereal, but this is at least doubtful. It is used as a solvent for essential oils, terpenes, etc., and on a large scale as an

CARBON DISULPHIDE (*Continued*)—
insecticide for moths, ants, grubs, and other pests; also for preventing infection of stored corn by insects. For these purposes the vapour is used in a strength of 1 part in 90. The liquid injected into the soil some way below the surface is a remedy for phylloxera of vines, each plant being treated with 5 ozs. on two occasions ten or twelve days apart. It yields sulphur dioxide when burnt, and is very inflammable, so much so that great care should be used in handling it, as the vapour being heavy is liable to flow along the ground to a naked flame at some distance, when it immediately ignites and the flame runs back with lightning rapidity to the source. Carbon disulphide is a poison when taken internally. (See Glasshouse Crops, and Insecticides and Fungicides.)

CARCASS MEAL—For composition and feeding value see Feeding Stuffs.

CARDOON—See Market Gardening.

CAR-LAND—Car-land or "cars" is the name given to stretches of land which have been reclaimed from what was originally swampy alluvial tracts, bordering streams. The "cars" are mostly under pasture, though the water is quite brackish. Car-land under arable conditions is usually troublesome, as the cropping is very strictly limited by the unusually high lime requirement. The largest area of car-land in England occurs in the Holderness area of Yorkshire.

CARSE—Carse is the name given to stretches of land on the banks of the rivers Forth and Tay, *e.g.*, Carse of Gowrie, Carse of Stirling, etc. Carse land consists of alluvial gravels and loam in some places, and of raised beach deposits in others. It is very fertile, highly farmed, and grows luxuriant crops of fruit—particularly raspberries, potatoes, hay and corn.

CASEIN—A protein present in the milk of all mammals, from which it may be prepared by precipitation with dilute acids after removal of the fat fraction. It is also obtained commercially by extracting fat-free soy-bean meal with sodium carbonate and reprecipitating with acid. It is used in the preparation of washable distempers and water paints, and for adhesives for use in the cold, in which connection it is much used in the construction of aeroplanes. It finds numerous applications in the sizing, paper, silk, and cotton trades, and in the preparation of imitation tortoiseshell, celluloid, ivory, etc. Minute percentages of the calcium salt (caseinogen), present in milk before precipitation, add considerably to the effectiveness of many sprays by reducing the surface tension of the liquid.

CELERY—See Market Gardening.

CELLULOSE—A polysaccharide obtained from the fibrous parts of plants in various forms which differ from one another in physical properties and also to some extent in chemical behaviour, although no chemical difference can be established. Cotton-wool and filter paper are fairly pure cellulose, and correspond to the formula $(C_6H_{10}O_5)_n$. X-ray analysis shows that the ultimate structure is

CELLULOSE (*Continued*)—
crystalline, and that the crystals are the same for all kinds of cellulose —cotton, wood fibre, etc., the differences depending apparently on the arrangement of these crystals.

From the point of view of both the farmer and the industrialist, its most noteworthy and useful property is its ability to take up water into its substance to the extent, if necessary, of many times its weight. This association may be brought about by either maceration, as in paper-making, or by means of reagents, such as alkalies and ammoniacal copper hydroxide (in which it is soluble), which are employed in the fibre and mercerizing industries. This property of absorbing and parting with water freely is of great importance to plants generally, playing a large part in the mechanisms of movement, transpiration, and drought resistance, and also is of considerable importance in the seasoning of timber, in which hurrying the process of drying produces an inferior product, probably owing to the appearance of phenomena analogous to those producible on the large scale by rapid drying of colloidal material.

In plants cellulose is often associated with pectins, as in flax, with lignins, as in jute, or with cutins, as in the cortical tissues.

Its use on a large scale in the manufacture of explosives, textiles, paper, cork linos, art silks, lacquer, vulcanized fibre, and insulating material for cold stores, as well as to a smaller extent in the production of power alcohol and other by-products of its destructive distillation, make it a substance of increasing interest to the agriculturist, if not in England, at least in many parts of the world. (See also Carbohydrates.)

CENTRIFUGE—See Separators and Centrifuges.

CHAFF AND CAVINGS—For composition and feeding value see Feeding Stuffs.

CHAIN, GUNTER'S—A chain invented by Professor Edmund Gunter, used in land measurement. It was made of 22 yards length—that is, 1 "acre's breadth"—and is divided into 100 links of 7·92 ins. Areas of land can be measured up very easily by its means, as it is only necessary to get the length and breadth in chains and decimals thereof and multiply them together. The area is thus obtained in square chains, and since 10 square chains is equal to 1 acre, the acreage is obtained at once by moving the decimal point one place to the left. A right angle can easily be set out with it as follows: A distance of thirty links is measured on the chain line from the point at which the right angle is to be thrown out. One end of the chain is held carefully at the thirty-link point and the ninetieth link at the end of the line, *i.e.*, at the point at which the right angle is to be made. The chain should then be pulled tight at the fiftieth link. The new line from the end of the chain line is thus at right angles to the same, for the sides of the triangle so formed are thirty and forty links respectively and the hypotenuse fifty links. This method, in essence, was used by the ancient Egyptians in building the pyramids. Between ordinary

CHAIN, GUNTER'S (*Continued*)—
outdoor summer and winter temperatures the length of a Gunter's chain varies by $\frac{1}{3}$ in.; this, however, only makes an uncertainty of 1 square yard per acre in areal measurements, so may normally be neglected.

CHAMOMILE (*Anthemis nobilis*)—This perennial plant is cultivated on a minor scale to meet the demand for its flowers, which, in a dried state, are utilised by the manufacturers of medicinal preparations.

There are two varieties of chamomile, one bearing single and the other double flowers, but the double-flowered variety is the one more commonly cultivated, as it blossoms in greater profusion. The crop prefers a dry soil, and the most valuable yields of flowers are obtained in districts with the maximum amount of sunshine. Seed may be sown in March, but as it is a perennial plant it may also be propagated by the division of established plants in the same month. The plants should be set out 9 ins. apart with 18 ins. between the rows. The flowers are gathered as they are produced and when they are freshly opened. Each day's picking is slowly and thoroughly dried before being stored.

CHARCOAL AND CHARCOAL BURNING—In those countries where communications are good and freights cheap, the older methods are being replaced by more modern ones which are less wasteful, more especially of by-products. In many countries, however, the old "meiler" may still be seen, notably in the more out-of-the-way parts of France, Austria, and Sweden. The charcoal meiler is built in two forms. For the burning of woods such as birch and buckthorn, as in France, the logs are stood on end leaning against one another at the top, often in two tiers so as to form a mound, which is then covered with turf. Apertures are left at the bottom to admit air, and in the centre is a space left to serve as a flue. In Austria, Germany, and Scandinavia, charcoal is more often made from the straight trunks of firs, in which case the bottom layer is formed of logs laid flat and side by side, the next is similar, with logs at right angles to those of the first lot; thus suitable ventilation from below is secured, and the remaining wood is piled flat above this with the larger boles in the centre; the whole is then covered with turf. In most countries, however, the wood is nowadays distilled in retorts from which wood tar, acetone, wood spirit, and acetic acid can be recovered in the distillates. The amount of carbon in the charcoal increases with the time of burning. Well-burnt charcoal has a bright black colour, and emits a clear note when struck. In this country, alder and willow are used for carbonization at low temperature, birch where long heating at high temperature is desired. This yields a charcoal of high carbon content, which may be "activated" for use as a gas absorber as in gas masks, by increasing the heat and limiting the supply of air. The charring of the ends of oak and elm stakes as a mode of preserving the buried ends when they are used as posts has been practised from very early times in this country; it is mentioned by Tacitus.

CHEESE AND CHEESE MAKING—The most convenient and inexpensive method for obtaining a solid, portable, palatable, and nutritious product from liquid milk is to turn it into cheese. Cheese making is a very ancient art, and cheese may almost be called a natural product, for it only anticipates the natural coagulation which takes place after ingestion of milk.

The most valuable constituents of the milk, *viz.*, the fat and case in are retained in the cheese with about 30 to 40 per cent. of water.

About half the solid matter of the original milk diluted with about 93 per cent. of water goes into the whey. (See Whey.)

Two methods are available to effect the separation—the rennet coagulation and the acid coagulation. Most types of cheese are made by the first method, which consists in adding a small proportion (about 1 to 3,000) of a solution of rennet which is extracted from calves' stomachs. The acid coagulation, which is used for only a few types, such as skim and cottage cheese, is usually effected by adding to the milk a small amount of an active starter culture which, under favourable temperature conditions, rapidly produces from the lactose sufficient lactic acid to coagulate the milk.

In many types of cheese, such as Cheddar and Emmenthaler (which is also known as Swiss or Gruyère), use is made of both methods of coagulation. In these cases the effect is primarily due to the rennet, but conditions are rendered more favourable by the addition of the starter culture, which later also helps to make the whey separate more readily.

The rennet causes a physico-chemical change in the caseinogen of the milk, whereby it is converted into casein. It was formerly supposed that the rennet split the casein molecule into a large coagulable molecule and a small soluble one, the so-called whey-protein or "molkeneiweiss." It is now generally agreed that the whey-protein is the albumin and globulin originally present in the milk. Ample evidence has been gathered to show that caseinogen and casein are chemically identical in every respect but one—namely, their ability to combine with calcium. The paracasein produced by the rennet has a greatly increased capacity to combine with calcium, thereby producing the well-known curd. One of the objects of ripening the milk with a starter culture prior to renneting is to transform some of the insoluble calcium salts into a soluble form ready to combine with the casein.

After the curd has reached the required degree of firmness, it is usually cut into cubes by means of suitable knives, so as to enable the separation of the whey to take place. The whey is expressed by the natural contraction of the curd, and the process is facilitated by raising the temperature and by the increase of acidity which usually occurs at the same time. A great deal of the art of successful cheese-making consists in continuing this process, by different methods according to the type of cheese, until the curd has attained that degree of firmness which is necessary for obtaining the qualities desired in the finished product. Various more or less empirical tests are used by cheese makers to assist in deciding when to conclude this stage, but

CHEESE AND CHEESE MAKING (*Continued*)—

there is room for the greater application here of scientific methods of pH determination.

The different constituents of the cheese all play a part in giving a satisfactory final product. For example, a Stilton cheese is put away in a rather moist condition so as to favour subsequent mould growth. On the other hand, if a Cheddar cheese is too moist, the growth of undesirable organisms may be encouraged, or when the cheese is cut it may rapidly deteriorate by drying out and cracking. Too much fat may give rise to a greasy condition, while too little in proportion to the casein yields a cheese that may be hard and dry. In a Cheddar cheese the amount of moisture (as well as of fat) plays a very important part in imparting to the finished product the desirable smooth, buttery consistency. A week after making, only traces remain of the lactose originally incorporated in the curd. The traces of mineral material, especially the lime and phosphates which are included with the curd, exercise an important buffer effect in maintaining the reaction of the cheese at the optimum for ripening. Stilton cheese does not usually have any starter added to it, but the addition of a small amount just prior to renneting has been found of use to prevent the reaction of the cheese becoming too alkaline, in which case discoloration ensues due to the growth of certain organisms (Cornish and Williams, *Biochem. J.*, vol. xi., No. 2, pp. 180-187, 1917).

Ripening may be said to commence when the curd has been moulded and pressed. In a cheese made with acid, like Cheddar, important but little understood changes occur in the curd during the first twenty-four hours after renneting. The proportion of protein soluble in 5 per cent. brine increases to a maximum and then decreases again. The subsequent stages of ripening seem to depend upon the previous formation of this brine-soluble protein.

Investigations carried out upon different types of cheese have shown that the process of ripening varies little in broad outline. It consists of the transformation of insoluble protein into a soluble form which consists of peptones, simple peptides, and amino-acids. This degradation is slowly effected by various enzymes present in the cheese, including those originally present in the milk, those added with the rennet, and those produced by the growth of bacteria and moulds.

Different types of cheese are ripened in different ways, and the final flavour is largely due, either to the type of bacteria incorporated in the cheese during making, or to the mould inoculation. Thus, Cheddar cheese is ripened by means of lactic acid bacteria; Emmenthaler by propionic acid bacteria; Stilton is a type where ripening is due to mould growth throughout the cheese; while in Camembert the effects are of external mould growth on the coat of the cheese.

A reliable pure milk supply is as essential in cheese making as in other branches of dairying. Frequent attempts have been made to overcome the difficulties associated with unsatisfactory supplies by pasteurizing the milk. This has been successful up to a point for Cheddar cheese making. The cheese maker is thus relieved of a great

CHEESE AND CHEESE MAKING (*Continued*)—

deal of responsibility by being able to turn out a product of more uniformly reliable quality. The pasteurized milk gives a higher yield of cheese due to the incorporation of more moisture, while losses of fat in the whey are considerably reduced. On the other hand, the resulting cheese ripens much more slowly, and gives only a very mild-flavoured product. Defects such as openness in texture are said to be accentuated by pasteurization, so that there is in some quarters a feeling that pasteurization of milk for cheese making ought to be avoided if the milk supply can be sufficiently improved. The newer method of using pasteurized milk, which is only heated to 140° F. and held at this temperature for half an hour, does not seem to injure the cheese-making properties of the milk, and produces a cheese which seems to be in every way comparable to that made from raw milk.

A recent development is the manufacture of "processed" or "pasteurized" cheese in which the mature product is ground up and then heated in a special steam-heated kettle, usually with some emulsifying agent such as sodium phosphate. The resulting product commands a ready sale, and is likely to increase in popularity.

A. T.

CHERRY—See Stone Fruit, under Fruit; for methods of preservation by refrigeration see Refrigeration.

CHICORY (*Cichorium Intybus*) is a deep-rooted perennial of the order Compositæ, with stems of from 1 to 3 ft. high. The leaves are fleshy and pinnatifid, and the flowers, which are azure-blue, occur in closely sessile clusters of two or three.

Chicory does not exhibit a strong partiality for any particular class of soil. Associated with grasses and clovers it produces good pasturage for cattle and sheep, especially on soils liable to suffer from lack of moisture. On the Continent its blanched leaves are used largely in salads, whilst the chicory of commerce is obtained from the roots. (See same subject under Market Gardening.)

CHLORIDE OF LIME ($CaOCl_2$)—**Bleaching Powder**—A commercial product containing, doubtless, both unchanged lime, calcium hypochlorite, and calcium chloride. It is made by exposing slaked lime to the action of chlorine gas, the lime being spread out on shelves in chambers to which chlorine is admitted, or, better, carried in a thin layer on stages which move slowly down a tunnel through which chlorine is being passed in the reverse direction. On treating its aqueous solution with a dilute acid, nascent chlorine is evolved which may be used for bleaching vegetable colours. This is usually effected by dipping the fabric first in the dilute acid bath and then in the bleaching solution. Agriculturally, this substance finds its principal application as a disinfectant. (See Calcium.)

CHLORINE (symbol Cl; atomic weight 35·457; atomic number 17)—A chemical element, gaseous at ordinary temperatures and pressures, with a bleaching action depending on the formation of nascent oxygen

CHLORINE (*Continued*)—
and hydrochloric acid in water. (See Chloride of Lime.) This substance occurs as chlorides in both plants and animals, but it has been shown that plants which normally contain it are able to live without it. This is not so with animals, which show a definite demand for chlorine ions for the formation of hydrochloric acid in the stomach in gastric digestion. (See Digestion.) It is also apparently quite necessary for the proper functioning of the central nervous system, reduction of chlorine ions in the blood to one-third the normal amount causing paralysis. It is excreted in the urine.

CIDER, Apples for manufacture of—See Apples, under Fruit.

CITRIC ACID ($COOH.CH_2C(OH).(COOH).CH_2COOH$) is present in the juice of lemons and limes, and to a less extent in many other fruits. It is commercially prepared by aerobic fermentation of glucose with species of *Citromycetes.* Chalk is then added to precipitate calcium citrate, which is then decomposed with dilute sulphuric acid. Reynolds Green considered that the small amounts found in sugar cane were due to a similar action of the cell protoplasm on the sugar. It was synthesized in 1881 by Grimaux. At 175° C. it decomposes, yielding aconitic acid, found in the roots of aconite and other plants. Alkaline citrates act as remote alkalies in medicine, as they become decomposed to carbonates in the blood. The acid is also used in dyeing, calico printing, and in the preparation of cooling drinks.

CITRUS FRUITS—For methods of preservation by refrigeration see Refrigeration.

CLOVER HAY—For composition and feeding value see Feeding Stuffs; also Manurial Values under same heading.

CLOVERS—See Legumes, Breeding of Herbage; Seeds Mixtures, Controversies, Past and Future; Wild White Clover.

COB NUTS—See Nuts.

"COCKLES," WHEAT—See Seed, Transmission of Plant Diseases by.

COCONUT CAKE—For composition, feeding, and manurial value see Feeding Stuffs.

COD-LIVER OIL as a source of vitamins—see Foods and Feeding; also Poultry, Nutrition.

COLD STORAGE—See Refrigeration.

COLLOIDS—See Soil Colloids and Humus.

COMBUSTION—Burning. The complete oxidation of a substance. It concerns the agricultural scientist in various ways. The combustion of an organic substance is often performed in chemistry to determine carbon and hydrogen with a view to ascertaining its empirical formula. For details see any simple textbook (*e.g.*, J. B. Cohen "Theoretical Organic Chemistry," p. 20). It is employed in the determination of the metabolizable energy of feeding stuffs, in which case a known weight of the feeding stuff is burnt in compressed oxygen in the bomb of a bomb calorimeter. The quantities are so chosen that there

COMBUSTION (*Continued*)—
is enough oxygen present to burn the feeding-stuff sample completely, and the heat generated is measured in the calorimeter by the rise in temperature of the surrounding water in which the bomb is immersed before the contents are ignited. The ignition is brought about electrically. From the results of such experiments the heat given out by each pound of the feeding stuff may be computed. Similar experiments on the dry matter of the urine and fæces, with a small correction, if necessary, for the heat of solution of the solids of the urine, afford figures from which the metabolizable energy of the feeding stuff may be calculated. Metabolizable energy = gross energy − (energy of excreta + heat of solution of urine solids). The spontaneous combustion of hay in stacks is due to the heat generated by fermentative changes due to alcoholic fermentation of starch and subsequent oxidation of the alcohol to acetaldehyde, which is highly inflammable at the temperatures likely to be generated inside stacks. There is danger of such fires occurring when the interior temperature is allowed to rise above 150° F.

COPPER—For compounds in common use see Insecticides and Fungicides; also Seed, Chemical Treatment of.

CORN SALES ACT, 1921 (SALE OF CORN BY WEIGHT)—The purport of the Corn Sales Act, 1921, is declared to be "to provide for the greater uniformity in the Weights and Measures used in the sale of Corn and other Crops, to amend the Corn Returns Act, 1922, and for other purposes connected therewith."

The expression "corn," when used in the Act, includes, where the context permits, wheat, barley, oats, rye, maize and the meal and bran derived therefrom, and any mixture thereof, and also applies to peas, dried beans, linseed and potatoes, and to the seed of grass, clover, vetches, swedes, field turnips, rape, field cabbages, field kale, field kohl-rabi, mangolds, beet and sugar-beet, flax, and sainfoin in like manner as it applies to corn.

The Act came into operation on the 1st January, 1923. Section 1 states that "from and after the commencement of this Act, every contract, bargain, sale or dealing relating to corn shall, unless it is made or had by weight only and in terms of and by reference to the hundredweight of one hundred and twelve imperial standard pounds, be null and void. Provided that this Act shall not apply to any contract bargain, sale, or dealing—

"1. for or relating to a less quantity of corn than one hundred and twelve imperial standard pounds;

"2. for or relating to corn which at the date of the contract, bargain, sale, or dealing is not within the United Kingdom, or to corn imported into the United Kingdom so long as the same shall remain in the warehouse, or store, or shed where the same shall have been first stored on importation;

"3. for or relating to corn imported into the United Kingdom in cases where such contract, bargain, sale, or dealing provides for delivery in the original bags in which the corn was imported (subject only to rebagging in replacement of damaged bags);

CORN SALES ACT, 1921 (*Continued*)—

"4. for or relating to corn bought or sold for export from the United Kingdom;

"5. for or relating to corn growing on or in the land or to corn unthreshed."

In conformity with the requirements for corn to be sold by weight the Act repeals words referring to the measure of corn contained in section 5 of the Corn Returns Act, 1882, which section requires buyers of corn, as described in the Act, to make weekly returns of purchases of British corn. Likewise, the annual and septennial average prices of British corn required to be computed by the Minister of Agriculture and Fisheries and advertised by him in the *London Gazette* is directed to be computed with reference to the hundredweight in lieu of the imperial bushel. The Act also provided for the minimum prices for wheat and oats under the Corn Production Acts, 1917 and 1920, to be expressed in terms of the hundredweight; the provisions of these Acts, so far as they relate to the minimum prices of wheat and oats, were repealed by the Corn Production Acts (Repeal) Act, 1921.

Section 5 of the Corn Sales Act states as follows:

1. Where under the provisions of any Act or award or other instrument any payments are to be calculated on the price or value of an imperial bushel of wheat, barley, or oats, those provisions shall have effect as if the payment were to be calculated on the price or value of sixty imperial pounds of wheat, fifty imperial pounds of barley, or thirty-nine imperial pounds of oats, as the case may be.

2. Where under the provisions of any Act or award or other instrument any payments are to be calculated on the price or value of any measure of wheat, barley, or oats other than the imperial bushel, the Minister of Agriculture and Fisheries, or, as regards Scotland, the Board of Agriculture for Scotland, may certify what number of imperial pounds ought, having regard to the foregoing provisions of this section, to be substituted for that other measure, and thereupon those provisions shall have effect as if the payment were to be calculated on the price or value of the number of imperial pounds so certified.

J. D. M.

COTTON—Certain well-defined climatic factors limit the commercial production of cotton. The range of those factors, however, owing to the diversity of habit of the different species of *Gossypium* cultivated, is sufficiently wide to bring within the list of cotton-producing areas all the major tropical and subtropical areas of the British Empire with the exception of Malaya. The cultivated forms of the genus *Gossypium* are perennials, though they are, in practice, almost invariably grown as annuals. The key to the understanding of cotton culture in all its forms lies in the system of branching. The growth of the main axis is indefinite, and in each leaf-axil is a main and an accessory bud. The main bud may develop with monopodial or vegetative growth, or it may develop as a sympodial, flowering branch. The branches from the lower leaf-axils are, if they develop, invariably monopodial, the upper, sympodial. The change from one

COTTON (*Continued*)—

type of branching to the other is abrupt; it may take place low down, giving a plant with few, one, or even no monopodial laterals, or it may take place high up on the main axis, giving a plant rich in monopodial laterals. In the former case the plant is early flowering, and may produce the first flower in thirty-five to forty days; in the latter case the plant is late flowering, the first flower, that on the first sympodial tertiary branch, appearing only after some 150 days.

A second characteristic, arising out of this habit of growth, is the absence of any defined inflorescence. As long as growth continues, sympodial branches will arise from monopodia and produce flowers. Hence flower and fruit production are coterminous with growth. The result is a harvest of indefinite length brought to a close only by those conditions which check growth. Commercial production—that is, production which gives an adequate yield—is limited to those areas where the season of growth is sufficiently prolonged to enable that yield to be obtained. The check may be one of temperature, and this determines the limits of latitude between which cotton can be grown; it may be one of humidity, as in Central India and South Africa, in which countries the sowing season is determined by the date of the first rains, and crop duration by the length of those rains, or, as in the Sudan, by the date of availability of water for irrigation; again, it may be a combination of these conditions, as in Northern India, where humidity, the break of the rains, determines the sowing season, and temperature, the onset of the cold weather, the duration of the crop. The prolonged harvest provides another limit to commercial production, in this case an economic one, for cotton picking is a laborious process only possible where cheap labour is available.

It is the lint, unicellular outgrowths of the epidermis of the testa, that constitutes the more valuable product of the cotton plant, the seed itself, as a source of oil and cake, possessing only a secondary importance. The crop is gathered as seed cotton from which the lint is separated in the process of ginning—the mechanical separation of lint from seed. The ginning percentage, a weight measure of the ratio of lint to seed cotton, is, therefore, not without importance, for it ranges in commercial varieties from 25 to 40. The value of the lint itself depends on "quality," the summation of a number of characters such as length, fineness, twist and fibre strength, which, like ginning percentage, have a varietal significance, and are only subject in a minor degree to climatic influence. The study of these characters, though it has proceeded far (Balls, "Studies of Quality in Cotton"), has not yet reached the stage at which the knowledge can be directly applied in breeding, and the same may be said of the characters which go to make up ginning percentage (Leake, *J. Genetics*, iv., 1915).

The cottons of cultivation fall into two well-marked groups characteristic of the Old World and the New. Inter-group sterility is the general rule, and appears to depend upon a numerical difference in chromosomes; a few inter-group crosses have been effected but produce a sterile F_1 plant. Within the groups complete fertility is the rule. As is usual with plants early introduced into cultivation, the nomenclature

COTTON (*Continued*)—

is obscure. The main cultivated forms, all of which are found within the Empire, are:

Gossypium herbaceum Linn. The species exhibits a number of forms, of which Broach cotton, cultivated in India, is a monopodial form, while sympodial forms are grown through Afghanistan, Persia, Asia Minor, and the whole of Southern Europe.

G. arboreum Linn. A monopodial form of this provides the sacred cotton of India, but it is not grown commercially. Sympodial forms in great variety constitute the bulk of the Indian crop. The staple is generally short, often less than ½ in.

G. barbadense Linn. This plant yields the "Sea Island" cotton, the most valuable cotton grown and having the longest staple, up to 1·8 ins.

G. hirsutum Linn. This species produces the staple "Upland" crop of America, the "bread and butter" cotton of Lancashire. Its cultivation has been carried to practically all the cotton-producing areas of the world.

G. braziliense Macf. This is a tree cotton, of which the distinctive feature is the adherence of the seeds to each other, whence is derived its name, kidney cotton.

Egyptian cotton, of the many varieties of which "Sakellarides" or "Sakel" is the best known, is a plant of mixed origin derived from two New World forms, *G. vitifolium* Lamk. and *G. barbadense* Linn.

Which of the above species is best adapted to cultivation in any particular locality depends on the major climatic factors which determine the length of the growing period and humidity. The determination of this is a matter of little difficulty, and the main agricultural problem is concerned with the determination of the varietal characters which, under a certain environmental stimulus, are correlated with high yield. This is a matter of sufficient difficulty, since, owing to the system of branching already explained, a given yield may be arrived at in totally different ways, but it is complicated by the vast number of races, often distinguishable only by their reaction to the environment, and by the existence of a considerable amount of vicinism. Since the yield may be the product of a first flush alone, or, if that fails, of a late flush or of a combination of two flushes, a direct comparison of yields is of small informative value, and the analysis of yield becomes a complex study of flowering curves on which bud- and boll-shedding curves must be superimposed (Balls, *Phil. Trans.*, B., 1915). The normal growth of the plant may be considered to be composed of an early period of vegetative growth followed, on the appearance of the sympodia, by a fruiting period. As the number of fruits to set increases, vegetative vigour is reduced, and may even practically cease. With the ripening off of the first bolls a supply of food material is released for further vegetative growth which automatically produces a further flush of flowers. The crop tends, therefore, to a periodicity which may, however, be upset by any adverse circumstances, climatic or otherwise, which induce shedding of flower buds or immature bolls. The factors which lead to such shedding are, thus, of considerable

COTTON (*Continued*)—

importance, and too little is known of this matter, which is receiving attention in the physiological work of the research station of the Empire Cotton Growing Corporation (Reports issued by the Corporation). But certain major causes are clear. Excessive rainfall, especially when the crop is grown on heavy soil, is an active stimulant of shedding. An early loss thus caused may be made up, under the influence of favourable weather conditions, on the second flush, and it has been found possible to calculate with a considerable degree of accuracy the yield from the daily rainfall data (Leake, *Proc. Roy. Soc.*, B., 103, 1928).

Yield is further affected by a phenomenon as yet not fully understood—the suppression of the lower sympodial branches. It is a phenomenon associated with high temperatures and low humidity during the early stages of growth, and is met with in the hotter and drier cotton tracts, such as the Sudan and the Punjab (Bailey, E.C.G.C., *Reports from Exp. Stns.*, 28-29). The matter assumes considerable importance when, as is frequently the case, a definite time limit is set to the productive season, a limit which may be a climatic one, temperature or humidity, or a biologic one, the onset of Bollworm (*Gelechia*) or Cotton Stainer (*Dysdercus*). The general trend in all cotton countries is to limit risks to the crop by forcing as far as possible a heavy first flush.

The cotton plant is very adaptable in the matter of soil, so much so that it has been said that the " cotton soils " derive their names less from the fact that these soils are well adapted to the cotton plant than from the fact that few other crops thrive on them. Cotton will grow on the heaviest clays under irrigation, but, where rainfall is high, a porous, well-drained soil is essential. It will grow also on soils having a high pH value. In most cotton areas the seed is sown in lines, on the flat or in ridges, and thinned to approximate even spacing in the lines. Inter-line distance and spacing vary considerably with the particular plant grown and the vigour produced by the local conditions.

It is not possible within the limits to give more than a very brief account of the different cotton areas of the Empire.

The West Indies—The islands of the Lesser Antilles form the main source of Sea Island cotton, though they produce a small amount of an inferior kind known as " Marie Galante " cotton. There is wide divergence in the sowing period of the different islands, and, in fact, in the main cotton-producing islands the climate is so uniform that cotton can be sown practically at any season. The major disadvantage is economic; with the small and inflexible demand for this very fine cotton a good harvest will saturate the market. On the agricultural side considerable damage results from Bollworm and, in the less closely cultivated islands where wild malvaceous plants offer a host, from Cotton Stainer. The former requires for its control, treatment and control of supply of seed for sowing and the co-ordination of sowing periods, so that a dead period may intervene between the successive

COTTON (*Continued*)—

crops; control of the latter necessitates destruction of the alternate wild host plants. The economic situation can be met by the organization of a supply of Marie Galante seed sufficient to plant up the normal area with this crop in times of Sea Island glut, for the market for this cotton is not restricted in the same manner.

Africa—The cotton areas of Africa fall into four natural belts. In the north is the desert area of the Sudan, where cotton is mainly grown under irrigation. Further south, embracing the Southern Sudan and Northern Nigeria, is a broad belt with a sufficient seasonal rainfall to allow of crop production without irrigation. An equatorial belt follows with ample rainfall throughout the year; this belt includes the cotton areas of Uganda and Northern Tanganyika. Lastly, and further south still, lies a belt with seasonal rainfall, which includes Nyassa, the two Rhodesias, and South Africa.

The Sudan—The main cotton area lies in the Gezira, south of Khartoum, where the recently constructed Senaar Dam has placed a large area of land under cultivation. This development scheme constitutes the largest example of co-operative planting in which the Government, the Syndicate, and the cultivator share the proceeds. Cotton, the only cash crop raised, is grown on a triple rotation; one season cotton and two seasons fallow. The land is ploughed and prepared with steam tackle, and sowings take place in June as soon as irrigation water is available. Picking commences in December and continues till April, frequent irrigation being given throughout the growing season. The limiting factor to the season is the supply of irrigation water. The variety grown is Sakel derived from Egypt. The soil is a heavy loess (60 per cent. clay being common), with a high pH value (9·5 common); drainage is lacking, and such conditions will inevitably raise problems of alkalinity, though the Blue Nile waters are not unduly saline. Of more immediate importance is the problem of "blackarm" (*B. malvacearum* E.F.S.). Suppression of the fruiting branches and shedding are also matters of considerable importance.

Sakel is also grown under unique conditions where the Gash and the Baraka debouch from the Eritrean hills to flood large inland deltaic areas at Kassala and Tokar respectively. At the latter place only does any of the flood water reach the sea. Cotton is dibbled in by breaking through the newly deposited silt to the older silt, and, except for light rain at Tokar, the crop is brought to maturity without further water supply of any sort. The areas sown fluctuate widely, and depend on the strength of the floods and the direction taken.

On the Nile below Khartoum are a series of pump-irrigated schemes on which a "hirsutum" cotton is grown. The flat tracts bordering the Nile are canalized and water supplied by pumping.

South of the Gezira the rains belt is entered, and cotton of the "hirsutum" type is grown on natural moisture. The season is a short one, and the crop must be sown at the earliest opportunity. Lack of population and the primitive life led by such races as the

COTTON (*Continued*)—

Shilluks, Nuers, and Nubas are factors against rapid progress, but the field is vast.

Nigeria—Cotton is grown throughout Nigeria, but it is only in the Northern Territories that the crop assumes importance. Elsewhere, alternative cash crops are available, and local cottons of the " peruvianum " and " vitifolium " forms are grown as catch crops, often mixed with yams. The northern cotton belt is a westerly extension of the Southern Sudan, and the cotton grown is a " hirsutum " form of the Allen variety.

Uganda—Owing to the presence of a comparatively dense population and of an adequate rainfall progress has been more rapid in Uganda than elsewhere in Africa. The country lies in the equatorial rains belt, and has only a relatively dry season in December to February. The plant grown is of the "hirsutum" type, of which a large number of races have been subjected to trial and selection, and the forms now cultivated may be considered to be distinctive. As is usual under such climatic conditions, the plant is sown so that the main flush may develop in the dry season; as is usual, also, where there is no check to growth, disease takes a heavy toll of the crop. " Blackarm " causes considerable damage, as do "stainers," " bollworm," and Jassid.

South Africa—The problem throughout South Africa, Nyassa, the Rhodesias, and the Union, is essentially one. A rainfall, seasonal and very variable both in duration and incidence, makes cotton a somewhat precarious crop, and in this respect it is comparable to India. But superimposed on, and masking, these risks has been the damage caused by Jassid (*Empoasca*). It is not too much to say that the success achieved by the isolation of a Jassid-resistant form has been the salvation of the commercial production of cotton throughout South Africa.

India—The Indian crop, varying widely as it does from year to year, totals some 5 million bales, and thus ranks second to America in the world's supply. The bulk of the cotton is, however, too short for use in Lancashire. In Broach a monopodial form of *G. herbaceum* is grown, and a monopodial form (*G. obtusifolium*) is grown in Madras in small quantity. The main cotton tract is, however, the Central Indian plateau, where numerous sympodial races of *G. arboreum*, some of which are given specific rank, are grown. *G. indicum* gives the " Bani " cotton; though it possesses the finest staple among the Asiatic cottons, its cultivation is restricted owing to the low ginning percentage (25 to 28). The mass of the crop here and in the United Provinces comes from races of *G. neglectum*, which receive favour owing to their high ginning percentage (up to 40). These are all of short staple. In the Punjab races of *G. hirsutum* are cultivated in the Canal Colonies, where irrigation permits early sowing and a prolonged season. In Madras " Cambodia " cotton is grown commercially. Throughout, small quantities of a degenerate form of *G. hirsutum* are to be found, the remnant of the efforts made in the middle of last century to establish this type.

COTTON (*Continued*)—

Considerable work has been carried out in the improvement of the indigenous cottons by breeding and selection, but in lack of organization of markets has lain, and still lies, the difficulty of their wide extension. The cultivator sells his seed cotton on a basis of ginning percentage alone, and there is thus a premium on high ginning percentage regardless of staple. Hence the extraordinary position that, for instance in the neighbourhood of Cawnpore, a cotton of such poor quality is grown, that it has been asked whether the grower knows that cotton requires two ends to spin. The lint of this is exported to Japan *via* Bombay, while the mills of Cawnpore are importing cotton from Bombay. Until a solution is found to these economic problems, work which is in progress for the improvement of the quality of Indian cottons must be largely sterile. The work of the Indian Central Cotton Committee, established as the result of the Indian Cotton Commission (1919), is mainly directed to this purpose.

Australia—A variable quantity of cotton of the " hirsutum " type is grown in Queensland. The critical agricultural factor here is the irregularity of the rainfall; but the dominant problem is economic, the attempt to grow what is essentially a cheap labour crop under conditions where cheap labour is unobtainable.

Other Countries—Small quantities are grown in other parts of the Empire, such as Malta, Cyprus, and Fiji, the latter having especial interest as being the only portion of the Empire in which kidney cotton (*G. braziliense*) is grown. This cotton has recently been introduced from New Guinea, and is replacing the Sea Island formerly grown, while attempts are being made to eliminate the objectionable " kidney " character. Reference, however, should be made to the Empire Cotton Growing Corpn. Repts. Expt. Stats., 1929-30.

H. M. L.

COTTON CAKE, Decorticated and Undecorticated—For composition, feeding and manurial value see Feeding Stuffs.

CREAM—Cream is the name which is given to the surface layer which forms on fresh milk when it is allowed to stand for some time. This layer which contains the fat globules was removed by skimming. The introduction of the separator (*q.v.*) has replaced the slower action of gravity by centrifugal force; the more complete extraction of the fat, and the great saving of time, more than compensates for the power required. Moreover, the separator throws out solid impurities from the milk and yields a fresher and purer product.

There is no standard for cream; the definition under the Public Health Regulations, 1927, No. 577, reads as follows: " Cream means that portion of the milk rich in milk fat which has been separated by skimming or otherwise and is intended for human consumption."

These Statutory Rules and Orders exclude the use of preservatives, colouring matter, and thickening substances in cream.

Thus, the popular association of " richness " in fat with " thickness," or in other words increased viscosity, is protected by law from unscrupulous vendors who, by the addition of such substances as gelatine, condensed milk, starch paste, or saccharate of lime, might give a fictitious

CREAM (*Continued*)—

value to cream on this popular evaluation. Cream samples now on the market (*Analyst*, 1928, p. 594) may vary from 20 to 60 per cent. of fat.

The percentage of solids-not-fat in the *serum* of cream (cream minus fat) should approximate to that of the milk from which it is obtained; but the practice of thinning with water may reduce this figure (see Lerrigo, *Analyst*, p. 489, 1928).

The conditions affecting the rising of cream are summarized in E. R. Ling's " A Text Book of Dairy Chemistry " (Chapman and Hall, 1930). In *homogenized* milk, in which the fat globules are broken down, the cream will not rise, but if such milk is diluted with fresh milk or separated milk, an enhanced and fictitious fat layer is formed; such milk is termed *viscolized* milk, a merely deceptive practice which has been prohibited in many states in America.

The exclusion of preservatives has necessitated very considerable alterations in the methods employed in the cream industry, and while the industry has been adapting itself to the new conditions the door has been opened to rivals. Tinned, sterilized, or evaporated creams, frequently low in fat, have been put on the market, and a more serious rival ("*artificial* cream") has gained a firm footing on land as well as on ships at sea. Many improved " emulsifiers " of varying size are now procurable by means of which unsalted butter, after melting in the requisite quantity of warmed milk or water, and dried milk powder can be reconstituted to a liquid which, when cooled, very closely resembles cream from fresh milk. When the ingredients are fresh and good, and the directions are closely followed, discrimination between the natural and manufactured product is very difficult. The method suggested by Richardson (*Analyst*, p. 335, 1928) of separating the butter fat by centrifugal force, after first shaking 5 grams of the artificial cream with a mixture of equal parts of benzene and methylated spirit (60 o.p.), suggests a difference in the stability of the adsorbed protein layer around the fat globules when compared with fresh cream which remains as an emulsion under similar treatment.

Further comparisons of the nature of adsorbed substances surrounding fat globules in natural and artificial cream seems desirable.

J. G.

CREAM, ICE—The manufacture of ice cream has become much more important during the last few years, and considerable improvement has been made in the methods of manufacture.

Ice cream making can be a very profitable outlet for surplus milk, although the introduction of emulsifiers has made possible the use of butter as an alternative ingredient to fresh cream. Champion (" The Manufacture of Ice Cream in a Small Commercial Dairy," *J. Brit. Dairy Farmers' Assoc.*, xli., 92, 1929) gives a brief outline of the methods adopted in a successful enterprise, and shows the possibilities of ice cream as a profitable side line. " Ice Cream Plant and Manufacture," by Robert Reid (A. J. Rayment, London), is a practical

CREAM, ICE (*Continued*)—
and concise book, while Turnbow and Roffatto's "Ice Cream" (Chapman and Hill) treats the subject in a more comprehensive manner.

S. B.

CREOSOTE—A mixture of phenolic substances obtained from wood tar. The name is also given to a similar mixture produced from coal tar, shale, bone oil, kelp, etc. For pharmaceutical purposes it is prepared from the distillate obtained when beech wood is burned in retorts, and has to be very thoroughly purified. Creosote is an excellent preservative for wood, and is in general possessed of germicidal qualities of a high order.

CRIMSON CLOVER—See Legumes, Breeding of Herbage.

CUCUMBER—See Glasshouse Crops.

CURRANTS, Black, Red and White—See Soft Fruits, under Fruit.

CYANAMIDE (CN_2H_2)—A colourless crystalline body important on account of its calcium salt ($CaCN_2$) which is produced by passing atmospheric nitrogen over a mixture of lime and carbon at 2,000° C., and is used to a considerable extent as a nitrogenous manure. (See Nitrogen, Fixation of Atmospheric and Calcium Cyanamide, under Fertilizers.)

CYTOLOGY—While the first discoveries of cytology were of fundamental importance to biology, its later developments have most significance for genetics and plant breeding. As early as 1665 it was observed by Hooke that certain plant tissues had a cellular structure, but cytology—the study of cells—did not really exist as a science until 1838, when Schleiden and Schwann concluded that every living organism is composed entirely of cells, which are therefore the units of structure and function. About 1844, Nägeli and later writers showed that cells only arise from the division of pre-existing cells; and not long afterwards it was realized that all cells, though they may differ widely in appearance, are alike in containing a living substance called protoplasm, the basis of life. Protoplasm itself consists of a nucleus, usually spherical, embedded in the more fluid cytoplasm, and is the only essential constituent of a cell. Plant cells, however, are nearly always surrounded by walls composed of cellulose or other substances. These constitute the framework of the plant, and are the most obvious structures to be seen when a section of plant tissue is examined under a microscope. Animal cells have no walls, though they may secrete a solid matrix, as in the formation of bone. Cytoplasm and nucleus, being both more or less transparent, are difficult to study when living; and for most purposes the practice is to treat the cells with reagents which kill them, and at the same time preserve the protoplasm so far as possible in its original structure, which is then made clear by the use of suitable stains. The technical methods by which this is accomplished have improved considerably in recent years, and photographs taken of cells before and after treatment show that surprisingly little alteration has been effected in the grosser features of the structure. The ultimate structure of protoplasm is a problem for the colloid chemist.

CYTOLOGY (*Continued*)—

In the period about 1880 it was finally realized that sexual reproduction consists, both in plants and in animals, in the union of a single cell—the egg-cell—derived from the female with another cell—the sperm-cell—derived from the male; and that the essential part in the process is the union of the nuclei derived from these two cells. Since cells only arise from other cells by division, it became clear that the chain of life could be regarded as a series of cell divisions, and that heredity is a consequence of the genetical continuity of cells by division. Special attention was therefore directed to cell division, and above all to nuclear division, which proved to be a far from simple process.

Cell division is initiated by condensation of the nucleus into a number of rod-shaped bodies, the chromosomes (Fig. 4, No. 1). These split longitudinally, and the halves pass to opposite poles of the cell, where they form the two daughter nuclei. The formation of a wall across the middle of the cell separates these nuclei and completes the division (Fig. 4, Nos. 2-4).

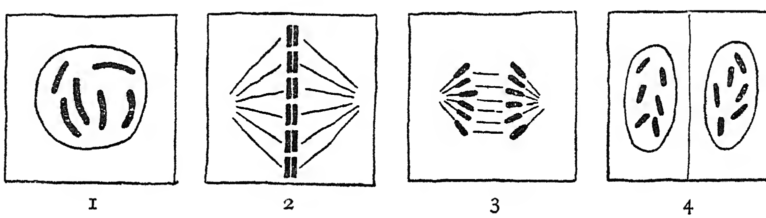


FIG. 4.—NOS. 1-4: SOMATIC CELL DIVISION, WITH SIX CHROMOSOMES.

Further study has shown that, with certain more or less well understood exceptions, the number of chromosomes appearing at division is the same in every cell of the plant or animal body, and in every individual of the same species. Moreover, in many species one or more of the chromosomes differ in size or shape from the others, and such differences appear in every dividing cell. This suggests that the chromosomes must retain their individuality to a great extent even when the cell is not dividing, despite the fact that the nucleus then appears to be practically homogeneous and the chromosomes can no longer be seen. They clearly undergo marked changes, the nature of which is unknown, but all observations tend to show that they reappear unchanged at every division, and may be regarded as self-perpetuating individuals. It follows that the act of fertilization, which consists of the union of two nuclei, must double the number of chromosomes; and we consequently find that the germ cells, male and female, contain only half the number of chromosomes found in the body cells, so that fertilization gives a new individual with the same chromosome number as its parents.

The germ cells contain this reduced number of chromosomes as the result of two divisions of special type, the *reduction* or *meiotic divisions*. An individual with 6 chromosomes in its body-cells derived

CYTOLOGY (*Continued*)—

3 of these—*A*, *B*, and *C*—from its mother, and 3—*a*, *b*, and *c*—from its father. At the reduction divisions these chromosomes associate in pairs, forming *bivalent* chromosomes; and in species in which the different chromosomes can be recognized it is found that this association is not haphazard, but is always between like chromosomes—*A* from the mother pairing with *a* from the father, *B* with *b*, and *C* with *c*. Chromosomes that pair in this way are said to be *homologous*. In species in which the chromosomes all look alike it is assumed with good evidence that there are still qualitative differences between them, and that paring still occurs only between homologous chromosomes; the two homologues in any one case being derived one from the mother and one from the father. At the onset of division, there-

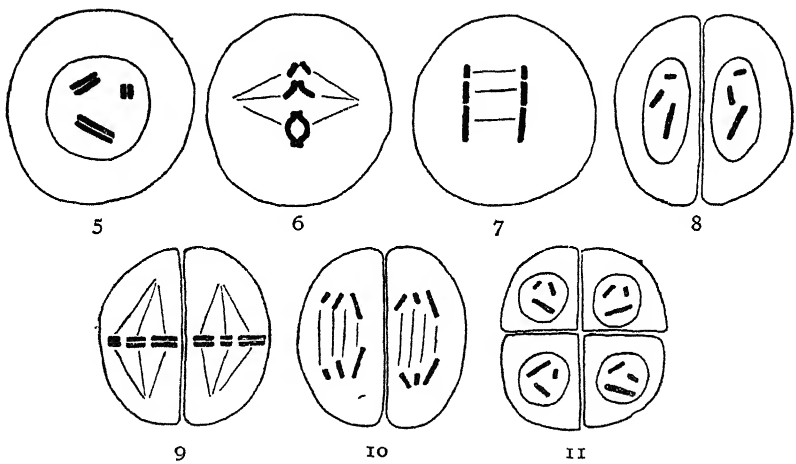


FIG. 5.—NOS. 5-11: REDUCTION DIVISIONS; SIX CHROMOSOMES, FORMING THREE BIVALENTS.

fore, the nucleus contains 3 pairs of chromosomes (Fig. 5, No. 5); and the two members of each pair separate from one another and pass to opposite poles of the cell (Fig. 5, Nos. 6, 7), instead of each single chromosome dividing into two halves. At each of the two poles a nucleus with 3 chromosomes, instead of 6, is reconstituted (Fig. 5, No. 8); and the two nuclei divide again almost immediately, this second division being exactly like an ordinary body-cell division, described above, so that 4 cells each containing a nucleus formed from 3 chromosomes are produced (Fig 5, Nos. 9-11). From these 4 cells the gametes, male or female, are derived. The first of these divisions is known as the *heterotype*, the second as the *homotype*, division.

The reduced number of chromosomes, 3 in the case described, is usually called the *haploid* number; while the somatic number, 6 in the same case, is called the *diploid* chromosome number. It will be realized that the segregation of the chromosomes at the reduction

CYTOLOGY (*Continued*)—
divisions is exactly parallel to the segregation of Mendelian factors (see Mendelism); and the chromosome theory of heredity supposes that the factors are actually carried by the chromosomes. Thus, in a heterozygote *Aa*, in which *A* was derived from one parent and *a* from the other, if the factors are carried by homologous chromosomes then *A* will be distributed to half the germ cells and *a* to the other half as Mendelian segregation demands. If another pair of chromosomes carry *B* and *b*, the two pairs of factors will segregate independently and the gametes will be produced in the proportion 1*AB* : 1*Ab* : 1*aB* : 1*ab*. Evidently there should not be more independently segregating factors, such as *A* and *B* above, than there are pairs of chromosomes; and it has in fact been shown in a few organisms—doubtless the number will be extended—that the factors fall into a number of linkage groups (see Mendelism) equal to the haploid chromosome number. The factors in one group are not completely linked—they become separated in a definite proportion of cases that varies with the factors involved—so that it must be possible for some sort of interchange to occur between the members of a homologous pair of chromosomes. It is believed that this takes place during the early stages of the heterotype division, but the details of the process need not concern us. It should be mentioned, however, that the linkage values found for the different factors in a single group have led to the theory that the factors are arranged in linear fashion along the chromosomes (T. H. Morgan, "The Physical Basis of Heredity," Philadelphia, 1919).

It will be understood that in recent years one of the principal tasks of cytology has been to show how various irregularities in inheritance can be produced through irregular chromosome behaviour. An important case is sex-linked inheritance in animals. In many animals with separate sexes it has been found that the chromosomes of the female and male are different. The female has a pair of chromosomes **XX**, while the corresponding pair in the male is **XY**; where **Y** may be absent, or recognizably different from **X**, or indistinguishable from **X** but presumed to be different from the breeding behaviour. Such a difference occurs in most animals; but in birds and *Lepidoptera* the position is reversed, the female being **ZW** and the male **ZZ**. In most cases **Y** carries no factors. Any factors carried by an **X**-chromosome shows sex-linked inheritance, of which a typical example is that the male transmits a character to his daughters, who do not show the character but transmit it to half their sons. Thus, in the fly *Drosophila melanogaster* a white-eyed male X**Y** produces gametes X and **Y**; while the normal red-eyed female **XX** produces only the gametes **X**. Matings from these two give: (1) **X**X, a normal female since white eyes are recessive; and (2) **XY**, normal males. The female **X**X produces gametes **X** and X, and mated with a normal male **XY** gives: (1) **XX**, a normal female; (2) **X**X, a normal female carrying the recessive character white-eyes; (3) **XY**, normal males; and (4) X**Y**, white-eyed males.

In poultry, as Punnett has pointed out, sex-linked inheritance makes it possible for the sex of a chick to be determined as soon as

CYTOLOGY (*Continued*)—

it hatches, if suitable matings are made (R. C. Punnett, *J. Genetics*, xxii, 395-7, 1930).

It will be noticed that the above discussion implies that the sex of an individual is determined irrevocably at fertilization, and depends simply upon whether an **X** or a **Y** sperm effected fertilization. Actually this is not quite true, since the sex of an individual may be reversed during development by appropriate conditions; so that an **XX** individual, which should be a female, becomes a male. Such an individual behaves genetically like a female, since mated with a normal female, **XX**, only female offspring result if they are allowed to develop under normal conditions. Sex-reversal is much easier in some species than in others, and individuals that are intermediate in sex may be formed. A well-known example is the free-martin, a sexually abnormal calf often borne as twin to a bull. Genetically the free-martin is a female whose sex has been partially reversed as the result of anastomosis of the bloodvessels supplying the two embryos, and is caused by the hormones from the male embryo being passed into the female embryo and so causing the latter to develop in the male direction (R. Goldschmidt, "The Mechanism and Physiology of Sex Determination," London, 1923).

The cytology of hybrids has produced many important examples of irregular chromosome behaviour. The first case was worked out by Rosenberg in the cross *Drosera langifolia* with 20 haploid chromosomes × *D. rotundifolia* with 10. In the reduction divisions of this hybrid 20 of the chromosomes pair to form 10 bivalents, while the remaining 10 remain unpaired, *i.e.*, *univalent*. The subsequent divisions are irregular, as might be expected, and the hybrid is sterile. Of the many similar cases that have been studied mention may be made of hybrids in wheat. The different wheat species have 7, 14, or 21 chromosomes (haploid). Those with 7 are of no economic importance; those with 14 include the macaroni wheats and the English Rivet wheats, and those with 21 the common bread wheats. Hybrids between any two wheats with the same chromosome number are fertile, and usually give normal Mendelian segregation; while hybrids between any two that differ in chromosome number are partially sterile, show unusual segregation, and give a bewildering mixture for their progeny. Both the sterility and the abnormal genetic behaviour of the latter hybrids have been related to the chromosome behaviour (A. E. Watkins, "The Wheat Species: a Critique," *J. Genetics*, vol. xxiii. 1930).

Similar irregularities in chromosome behaviour, typically the production of both bivalent and univalent chromosomes at the heterotype division, have been found to characterize many wild and cultivated plants; and is believed to show that the forms in question owe their origin to a chance hybridization between two species with different numbers of chromosomes (*e.g.*, K. B. Blackburn and J. W. H. Harrison, "The Status of the British Rose Forms as determined by their Cytological Behaviour," *Ann. Bot.*, xxxv., 1921). In such cases normal sexual production does not usually occur; reproduc-

CYTOLOGY (*Continued*)—

tion being either vegetative, apomictic—seed development from unreduced diploid cells of the embryo-sac—as in many *Rosa* forms (G. Täckholm, *Acta Horti Bergiana*, vii., 97-381, 1922), or partheno-genetic as in *Hieracium*. In general it may be said that plants in which chromosome behaviour during the reduction divisions is irregular, are characterised by partial or complete sterility; non-functional pollen and egg-cells being frequent, as might be expected, and seed production consequently low.

Among cultivated plants, irregular chromosome behaviour occurs in many fruits, but the resultant sterility need not necessarily prevent the crop from being good. Thus, chromosome behaviour is irregular in the "Blenheim Orange" apple; but in the apple a good crop will be obtained if only 5 per cent. of the flowers give mature fruit, and it may happen that the development of the fruit is parthenocarpic, *i.e.*, it develops without fertilization having occurred (M. B. Crane and W. J. C. Lawrence, "Genetical and Cytological Aspects of Incompatibility and Sterility in Cultivated Fruits," *J. Pomology and Hort. Sci.*, vii., 276-301, 1929). In most fruits, however, a more important feature affecting fertility is that many varieties cannot be fertilized by their own pollen, but only by the pollen of certain other definite varieties (*e.g.*, M. B. Crane, "Self-Sterility and Cross-Incompatibility in Plums and Cherries," *J. Genetics*, xv., 301-322).

Besides throwing light on the problems of reproduction and inheritance, cytology has contributed to a fuller understanding of a related problem—the origin of new forms or species. As an example reference may be made to the so-called polyploid series, in which the chromosome numbers increase in geometrical progression. Such series are very common in plants, and mention has been made of one case, that of the wheat species. Tetraploid varieties sometimes arise under experimental conditions by a simple doubling of the chromosomes (*e.g.*, if reduction fails to occur, so that diploid gametes are produced), the new individual containing four chromosomes of each kind instead of two, and being exactly like the diploid except for its larger size. There is evidence, however, that the polyploid series found in nature arose in most cases by a somewhat different method—namely, hybridization followed by chromosome doubling, as first suggested by Winge ("The Chromosomes: Their Numbers and General Importance," *C. R. Trav. Lab. Carlsberg*, xiii., 131-275, 1917), and observed to happen under experimental conditions on several occasions in recent years. Here, a species A with 2a chromosomes crossing with a species B with 2b chromosomes gives a sterile diploid hybrid with a+b chromosomes, while from this a fertile tetraploid will 2a+2b chromosomes arises by chromosome doubling. Thus *Primula floribunda* crossed with *P. verticillata* gave the sterile diploid *P. kewensis*; and from the latter a fertile tetraploid arose as a bud-sport, coming therefore from a somatic cell with twice the usual number of chromosomes, probably the result of an irregular somatic division (W. C. F. Newton and C. Pellew, "*Primula kewensis* and its Derivatives," *J. Genetics*, xx., 405-466, 1929). It is perhaps more usual, however,

CYTOLOGY (*Continued*)—

for such cases to arise from the production of occasional diploid gametes by the sterile hybrid. In a wide cross, as in the radish × cabbage, chromosome pairing may fail entirely at the reduction divisions, leading inevitably to the occasional production of gametes with the unreduced, diploid, number; and two such gametes uniting would give a tetraploid (G. Karpetchenko, "The Production of Polyploid Gametes in Hybrids," *Hereditas*, ix., 349-368, 1927). Besides this example, *i.e.*, *Raphanus* × *Brassica*, which has given fertile giant tetraploids, several similar cases have been recently reported; and indirect evidence favours such an origin for the polyploid wheats (A. E. Watkins, *loc. cit.*).

This production of new, constant, and fully fertile forms by hybridization may clearly prove to be fundamental to plant-breeding methods of the future.

General References.—E. B. Wilson, "The Cell in Development and Heredity," 1231 pp., New York, 1925; L. Doncaster, "Cytology," 280 pp., Cambridge, 1920; L. W. Sharp, "An Introduction to Cytology," 452 pp., New York, 1921; E. B. Babcock and R. E. Clausen, "Genetics in Relation to Agriculture," 673 pp., New York, 1927. A. E. W.

DAFFODIL—See Bulb Growing.

DAIRYING—Type and Conformation of Dairy Cattle—The more important economic requirements of a dairy cow are: (1) good milk-yielding capacity; (2) capability of regular breeding; (3) good constitution; and what is commonly referred to as the dairy type of cow is one which appears to possess the visible characters usually considered to be associated with such requirements. The original ideas as to the best conformation and type for the dairy cow were based almost entirely on the observations of cattle-men rather than on accurate measurements and records. Since the majority of these observers worked with one breed of cattle, there has tended to be confusion as to which characteristics are breed points, and which indicate the general milk or dairy tendency. Again, most lovers of cattle desire an animal which possesses symmetry and beauty of form, and it is impossible to decide the extent to which this may influence the judging of cattle. During recent years many attempts have been made to assess the true value of various external characters as indications of milk-yielding capacity. Among the workers who have studied this problem, Guenon should be mentioned as a pioneer, although his conclusions in respect of the escutcheon have not been substantiated. The results of more recent work are given by Gowen in "Milk Secretion" (Williams and Wilkins Company, 1924) and "Cattle Breeding" (*Proc. Scot. Cattle Breeding Conf.*, Oliver and Boyd, 1925, Edinburgh and London.) F. H. Garner ("Thesis for M.Sc. University of Minnesota," 1927) gives a good bibliography and discussion, as well as work of his own. The general conclusions of these workers make it clear that the value of conformation as a means of forecasting milk-yielding capacity is very limited, but that certain points in connection with the mammary

DAIRYING (*Continued*)—

system are of value, more particularly size and quality of the udder, size of rear udder, milk veins, and size of the milk wells. It does not follow that because certain points in conformation are not closely correlated with milk yields that these points are not worth considering, since they may be correlated with such qualities as breeding, constitution, or other less important but desirable characters. The work of Swett, Graves, and Miller (*J. Agric. Res.*, vol. xxxvii., 1928) suggests that in skeleton growth and in the weight and size of the internal organs there is little difference between a typical dairy and beef type of cow; the essential difference lies in function and fleshing properties. During recent years a considerable advance has been made in our knowledge of the ductless glands of the body, particularly their importance in the control of the body functions, and Crew (*J. Roy. Soc. of Arts*, vol. lxxviii., 1930) indicates the effect on type of differences in the activity of these glands.

It is well known that feeding and management influence the appearance of animals considerably, and this tends to complicate the use of external characters as a means of evaluating other qualities.

Many publications deal with the points of a dairy cow, and a good diagram is given by Mackintosh ("Dairy Cattle," E. Benn, Ltd., London, 1923) and by Henry and Morrison ("Feeds and Feeding," 19th edit., 1928). Also, among the various score cards drawn up for cattle judging, that prepared by the Agricultural Education Association of the "dairy heifer" and the "dairy cow" represent the result of careful compilation. (See *Agric. Progress*, vol. vii., 1930.)

Size of Dairy Cows—It is well known that large cows tend to yield more milk than small cows, but the work which has been done to compare the economic efficiency of large and small cows does not show any very clear advantage for either; for example, Nevens ("Breed and Size of Cows as Factors affecting the Economy of Milk Production," *J. Dairy Sci.*, ii., 1919) concludes that in the Holstein breed the larger cows were the more economical milk producers, whereas in Jerseys and Guernseys the smaller cows were the more economical producers of butter fat.

FEEDING OF DAIRY STOCK—**Food Requirements of Dairy Cows**—Our knowledge of the food nutrient requirements of dairy cows is based on a considerable amount of research work and on practical trials; the table on p. 246 shows the standards recommended in the Report of the Departmental Committee on the "Rationing of Dairy Cows" (*H.M. Stationery Office*, 1925). The protein is expressed by a new term, "protein equivalent," which is calculated by adding to the digestible true protein one-half of the non-protein nitrogenous matter.

Winter Feeding—**Selection of Rations**—There are two general aspects to be considered when selecting rations for dairy cows; the first is that the dairy cow is a useful and economical means of utilizing the products of the farm, and the second that high milk yields per cow

DAIRYING (*Continued*)—

tend to reduce the cost of milk production so that rations must be compounded with a view to maximum production.

Average Live Weights and Maintenance Requirements per Head, per Day, of Cows of the Dairy Breeds.

Breed.	*Average Live Weight.*	*Maintenance Requirements.*	
		Starch Equivalent.	*Protein Equivalent.*
	Lbs.	Lbs.	Lbs.
South Devon	1,450	7·6	0·86
Lincoln Red Shorthorn Longhorn ..	1,300	7·1	0·77
Dairy Shorthorn British Friesian	1,250	6·9	0·74
Blue Albion Welsh Black Devon	1,150	6·6	0·68
Red Poll	1,100	6·4	0·65
Ayrshire	1,000	6·0	0·60
Guernsey	950	5·8	0·57
Kerry	850	5·3	0·51
Jersey	800	5·1	0·48
Dexter	650	4·4	0·39

Production Standards (per 10 lbs.) in Respect of Milk of Varying Qualities.

Fat Content of Milk (per Cent.).	*Starch Equivalent.*	*Protein Equivalent.*
	Lbs.	Lbs.
3·7 –3·8	2·50	0·60
3·9 –4·0	2·60	0·63
4·2 –4·3	2·75	0·67
4·45–4·55	2·87	0·70
4·7 –4·8	3·00	0·74
5·2 –5·3	3·25	0·81

The point needing primary consideration, therefore, is the quantity of home-grown foods available, and while it is quite probable that an ideal ration cannot be prepared from these foods alone, a satisfactory ration may be built up by the judicious purchase of suitable foods.

The more common bulky foods are hay, straw, silage, roots, cabbage, and marrow-stem kale, and the greater the variety of these foods which are grown on a farm, the less is the danger of a shortage of fodder due to abnormal weather conditions in any one year. The utilization of the more concentrated home-grown foods in the ration will depend on market values, and sometimes it may be more profitable to sell these products and replace them by purchased foods. A method of comparing the relative value of different foods is given in the Report

DAIRYING (*Continued*)—

of the Departmental Committee on the Rationing of Dairy Cows, and the *Journal of the Ministry of Agriculture*, November, 1929, also offers helpful notes.

The choice of purchasable concentrated foods in this country is so varied that no difficulty need be experienced in selecting a suitable winter ration; for example, when there is a shortage of bulky foods the deficiency may be made good by such foods as sugar-beet pulp, coconut cake, and some of the lighter concentrates such as bran.

A point in the compounding of concentrated food emphasized by Hammond ("The Physiology of Ruminant Digestion," *Vet. Record*, No. 17, vol. ix., p. 343 April, 1929) is that with the modern dairy cow when fed a high proportion of concentrated foods, it is most important to avoid a large proportion of heavy meals such as uncooked wheat, bean meal or maize meal, which tend to produce a doughy mass in the stomach unless mixed with lighter or flaky forms of concentrates.

The importance of a mixed diet has been emphasized during recent years, since the protein from single plants seldom supplies a suitable balance of the amino acids necessary for animal nutrition; also animals fed on a mixed diet are less liable to suffer from a deficiency in vitamins or minerals.

Orr ("The Rôle of Vitamins and Minerals in Stock Feeding," *J. Min. Agric.*, vol. xxxvii., April, 1930, and May, 1930) gives a good summary of the present-day knowledge of this subject. He concludes that in practice there is little likelihood of a deficiency in vitamins except perhaps vitamin D, and that if deficiency is suspected this can be made good by green foods, cod-liver oil (vitamins A and D), or yeast (vitamin B), rather than by the purchase of expensive foods alleged to be rich in vitamins.

Mineral deficiencies generally may be made good by ground limestone, common salt, bone meal, and in the goitre districts very small amounts of potassium iodide.

A concise discussion on the more important items needing attention in the rationing of cows is given by Mackintosh ("Feeding of Dairy Cows," National Institute for Research in Dairying, University of Reading), while Henry and Morrison ("Feeds and Feeding") give a much more exhaustive treatise on the subject. See also articles: Foods and Feeding, and Feeding Stuffs.)

Summer Feeding—The staple food of cows in summer time is grass, and grazing cows on pasture land provides one of the cheapest means of feeding, as the food is collected by the cows themselves and no labour is involved in handling it. During recent years it has become more obvious that in many cases grass has not been utilized to the best advantage, and increased attention has been devoted to the more economical and extensive use of pasture grass. Improvement has been brought about by a careful study of the growth of pasture and the introduction of systems by which wasteful feeding is avoided, also the grazing period is extended as much as possible.

One point which is now more generally realized is that young grass

DAIRYING (*Continued*)—

contains a higher protein content than is needed for a balanced ration, and while this does not appear to injure the health of cows for the short period such grass is normally available, it is obvious that more effective control of rationing during the grazing period is highly desirable. This can be effectively accomplished by the use of smaller fields and by the adoption of a rotational method of grazing, the cows running on a comparatively small area while other fields are making growth. This method reduces the extent of fouling of grass by cattle walking over it, and makes it possible to carry out harrowing of cow droppings, as well as summer manuring, if desired. Extension of the grazing season may be obtained by careful management in early spring and late summer. Growth of grass in spring can be accelerated by the application of fertilizers in late winter, but on most land considerable harm may be done by "poaching" if cattle are turned on grass too early; it is desirable, therefore, to select the driest field for producing the earliest bite of grass. Growth in late summer is governed largely by available moisture, but much can be done to extend the autumn grazing period by systematic grazing of pastures and aftermath.

Supplementary Foods to Grass—Correct rationing of cows during the summer is largely dependent on accurate estimates of the quantity and composition of the grass available. Such estimations are not easy, and help may be obtained from the figures published by Woodman *et al.*, *J. Agric. Sci.*, xix., p. 236.

PERCENTAGES OF DRY MATTER.

Season .. .. *System of cutting*	1925. *Weekly.*	1927. *Fortnightly.*	1928. *Three-weekly.*
	Average per Cent.	*Average per Cent.*	*Average per Cent.*
Digestible crude protein	19·97	18·75	16·66
Digestible "carbohydrates" ..	36·10	36·50	38·65
Digestible fibre	12·08	13·10	13·64
Production starch equivalent per 100 lbs. of dry matter	67·74	69·87	69·39
Nutritive ratio, 1:	2·79	3·13	3·63

The composition of grass is shown to be highly nitrogenous in the young and leafy stage, but as the plants grow older they become less nitrogenous.

When cows have access to abundance of young grass they will usually consume enough to provide for maintenance and up to 3 gallons of milk per day. Although this ration is unnecessarily rich in protein, there is little chance of effecting economy by restricting the consumption of grass and feeding other foods. Heavy-yielding cows, however, need a proportion of concentrated food, and for this purpose it is best to use foods rich in carbohydrates, such as maize or maize

DAIRYING (*Continued*)—

products, dried grains, wheat offals, oats, etc. By this means it is possible to feed heavy yielding cows with a fairly well-balanced ration, but cows yielding 3 gallons or less per day usually receive more protein than is necessary during the grazing season. When cows are grazing on small plots it is a good practice to allow the heavy milkers access to fresh grass and the poorer milkers to follow them; by this means cows which require the largest amount of food can gather it quickly, and also those cows which eat the grass richest in protein are those which are being fed with balancing carbohydrate foods.

The Intensive System of Grass-land Management—It is well known that nitrogenous manures are usually most effective in producing heavy crops, but the objection to the use of nitrogen on pasture land has been that the grass is not well eaten. During recent years many experiments have been done, and as a result some of the objections to the intensive manuring of pasture land have been overcome. Thus it has been shown that the use of phosphate and potash in conjunction with dressings of nitrogen are desirable, as well as the use of sufficient lime to prevent the land becoming sour. The palatability of the grass is good provided it is eaten down in the young leafy stage, and in order to do this it is essential to have small fields and stock heavily as soon as the grass is 4 to 6 ins. high.

In one experiment the increases in the stock-carrying capacity of pasture as a result of dressings of about 3 cwts. of sulphate of ammonia applied in three dressings during late winter and early summer were 30 per cent., 47 per cent., 31 per cent., and 8 per cent. in four successive years, the increases being proportional to the summer rainfall (*Ann. Rept. Nat. Instit. for Res. in Dairying*, 1928).

Calf Feeding—Economy in calf feeding on the dairy farm is largely a question of the minimum amount of whole milk which may be fed to a calf and still produce good results. No satisfactory milk substitute has been found for the very young calf, but if 1 gallon of milk is fed daily until the calf is about six weeks old and then other foods substituted, good growth can be obtained. All changes in feeding should be made gradually, the milk being replaced by water, until at six to eight weeks of age the calf is receiving about 6 quarts of water daily, together with a little hay and about 2 lbs. of cake and meal mixture. This mixture should be easily digestible, and contain 20 to 25 per cent. albuminoids, 5 to 8 per cent. of oil, 45 to 55 per cent. carbohydrates; such foods as linseed cake, oats, bran, bean meal and maize meal have proved satisfactory ingredients, while the addition of 5 to 10 per cent. of fish meal provides the very necessary mineral constituents. On farms where separated milk is available it is possible to introduce this in place of whole milk at about three weeks of age, and it may be economical to continue for six months. In this case the meal mixture should contain less albuminoids, and fish meal or minerals are unnecessary.

Feeding of Young Dairy Stock—The nutritive requirements of young stock reared for ultimate inclusion in the dairy herd are not easily

DAIRYING (*Continued*)—

expressed by any simple table, as is the case with full-grown cows, since neither the live weight nor the daily live weight increase gives a reliable basis for stating standard requirements. Again, all parts of an animal do not grow simultaneously at relative speeds; for example, a calf is comparatively longer in the leg than a cow; these changes with age in the rate of development of different parts of the body make it desirable that sufficient food should be supplied at all stages to secure maximum efficiency and well-balanced growth.

Henry and Morrison ("Feeds and Feeding," 19th edit.) give a table which may serve as a guide for the rationing of young dairy stock, but whatever standards are used, it is most important to note the effect of a ration on the condition of young stock and make changes when they appear to be necessary.

The table below shows approximate sizes, and some simple but satisfactory indoor rations for well-grown dairy shorthorn heifers at three separate ages:

Age of Animal.	*Live Weight (Lbs.).*	*Height at Withers (Ins.).*	*Ration.*			
			Typical Constituents (Daily).	*Dry Matter.*	*Starch Equivalents.*	*Protein Equivalents.*
Birth ..	90	29·0	Milk, 10 lbs.	—	—	—
6 months	320	39·5	Hay, 5 lbs. Roots, 8 lbs. Concentrated foods, 3 lbs.	9·0	4·69	0·93
12 months	520	44·5	Hay, 12 lbs. Roots, 20 lbs. Concentrated foods, 2 lbs.	14·52	7·62	1·35
24 months	900	49·5	Hay, 16 lbs. Roots, 25 lbs. Concentrated foods, 2 lbs.	18·50	9·57	1·68

The summer feeding of young stock when grazing is comparatively simple, since little or no supplementary foods are needed, except for calves under one year, which are often improved by about 2 lbs. daily of a carbohydrate concentrate, and heifers during the month before calving benefit greatly by a balanced concentrated food at the rate of 3 to 6 lbs. daily.

MANAGEMENT AND MAINTENANCE OF THE DAIRY HERD—BREEDING: Inheritance of Milking Capacity—Milk-yielding capacity in the cow may be limited for a variety of reasons, possibly the urge or tendency to secrete large quantities of milk is the result of particularly efficient secreting glands capable of exercising priority of claim over other body functions in the demands on the blood, but, in addition,

DAIRYING (*Continued*)—

a good digestion is needed as well as a strong constitution capable of continuous hard work. It would be difficult, therefore, to imagine that the inheritable qualities of milk secretion are controlled by a single genetic unit such as that controlling the presence or absence of horns, and it is now generally accepted that milk and fat secretion are influenced by a number of genes or factors.

Turner (*Univ. of Missouri Res. Bull.* 112) puts forward a theory as to the mode of inheritance of milk and fat yield, and suggests that many of the genes favouring high production are dominants; if this is correct, it provides a simple explanation of the good milk-producing ability usually possessed by cross-bred cows which are the progeny of one high and one low producing parent; it also explains the large proportion of inferior animals that are produced when such cross-bred animals are bred together.

The work of Buchanan Smith (*J. Dairy Res.*, vol. i., No. 2, May, 1930) indicates the probability that the inheritance of milk is partially controlled in a sex-linked manner, and if this is substantiated an advance has been made in the means available for choosing a dairy sire.

The production of large quantities of fat by a cow is dependent on the quantity of milk produced and on the percentage of fat contained in the milk, so that when discussing the inheritance of fat, it is necessary to explain whether weight of fat or percentage composition of the milk is meant. When large quantities of milk are produced there is a tendency for the fat content to be lower (Gaines, "The Relation between Percentage Fat Content and Yield of Milk," *Univ. Ill. Agric. Exp. Stat. Bull.* 245). There is no doubt, however, that the combination of high milk production and high fat percentage is possible, and that both are inherited; probably they are inherited independently, and consequently animals possessing both characters are more difficult to breed than when only one character is desired; also, the production of quantity and quality needs the utilization of more energy and must be a greater tax on the producing activities of the cow.

Until recently very little attention had been paid to the solids-not-fat content of milk, but the difficulty experienced in some herds of maintaining the legal minimum standard of 8·5 per cent. has focussed attention on this point. If there is one cause more than another which results in a low solids-not-fat content in milk, it is that certain families of cows yield such milk, and since these animals have not been known owing to the lack of tests, the defect has not been noticed and eliminated by careful breeding.

Choice of a Dairy Sire—The importance of a good sire in any breeding herd is well known; the difficulty in choosing a sire for the dairy herd lies in the fact that milking qualities cannot be measured directly in the male, and the value of conformation as an indication of dairy qualities is very limited. It is usual, however, to use conformation as one means of selecting dairy sires, and it would be a mistake to discontinue its use until the genetics of the subject is more advanced.

A study of the ancestry of a bull is one of the most obvious aids to

DAIRYING (*Continued*)—

selecting a suitable sire. The method is undoubtedly of value, and the fact that it has sometimes proved disappointing is not a reason for condemning it, but rather indicates the need for using it in a more careful manner.

According to Galton's law, the importance of the ancestors of an animal may be regarded as influenced to the extent of 50 per cent. by the two immediate parents, 25 per cent. by the four grandparents, with corresponding decreases in earlier generations. For the study of ancestry, therefore, it appears desirable to consider every animal in the pedigree for three generations, for the influence of individual animals beyond the fourth generation is so small that they need little or no consideration. In respect of the female ancestors, it should be possible to know all calving dates and lifetime milk records which will indicate milk-yielding capacity, as well as assist in showing breeding ability and constitution. The extent to which line breeding or inbreeding has been practised may be noted from the ancestry, and conclusions drawn as to the purity of the genetic characters, since inbreeding tends to produce homozygous characters and, therefore more certain breeding qualities.

Proved Sire—The ultimate value of a bull is decided by his progeny, and it has become customary to apply the term "proved sire" to a bull which has been found to impart a high milk-yielding capacity to his daughters. It is not possible to evaluate a bull by this means until he is five or six years old, but a bull proved to be a good transmitter of milking capacity is of more use in the dairy herd than any sire of fashionable breeding but unknown transmitting ability. There is little doubt that the progeny test is the best means known at the present time for testing dairy bulls, and the more extensive use of proved sires is likely to give better breeding results than any other method.

Functions of Breed Societies—The herd books of the various breed societies are the principal means used by these societies for keeping their own section or family of cattle free from interbreeding with other cattle. Each breed society lays down general regulations as to the type which represents the ideal for the breed, but individual breeders keep their own records, and usually concentrate on certain families within the breed, thereby producing a uniformity of type in their herds.

The general effect of isolating breeds in this manner is to avoid crosses of widely different types of cattle, and by breeding together more closely related stock there is a tendency for genetic characters to become purer and more certain of transmission. Since some of these characters are good and some bad, it is essential that the more inbred animals become the more ruthless must be the elimination of undesirable animals.

The maintaining of pure genetic stock is not the sole object of the breed societies, and many of them have introduced schemes for the measurement and publication of the productive and transmitting ability of their animals. Examples of these schemes are the milk

DAIRYING (*Continued*)—

record "Advanced Registry" scheme of the English Guernsey Cattle Society, and the Register of Merit for bulls established by the Dairy Shorthorn Association. Details regarding the activities of the breed societies may be obtained from the secretaries of these societies, and up-to-date lists of addresses are published in most of the year books issued by the agricultural and livestock press.

Milk Records—Milk records provide breeders with an excellent and easily expressed measurement of the production value of dairy cows, and greatly simplify the difficulty of improving cattle in respect of dairy qualities. There are other advantages in keeping milk records, not the least being the possibility of systematic rationing of cows based on their production. Milk records may be divided into two general groups—"official" and "private." The former are checked by a controlling body or association, and the latter are kept by a farmer for his own private use, and are not accepted by breed societies or potential purchasers of the cows.

In England and Wales official milk recording is carried out by milk-recording societies working under the regulations of the Ministry of Agriculture. Accuracy of the records is ensured by recorders paying surprise visits to farms and checking the yields of milk at least one day in six weeks.

The recording of quality as well as quantity of milk is of great importance; thus Mackintosh (*J. Brit. Dairy Farmers' Assocn.*, vol. xli., p. 64, 1929) emphasizes the improvement which might be effected in the English scheme for milk recording by more complete regulations regarding the testing for butter fat and the utilization of these tests for the calculation of official butter-fat records. It is interesting to note that a standardized scheme for testing and calculating lactation butter-fat records has been adopted recently by the Dairy Shorthorn Association, thus recognizing the importance of quality as well as quantity of milk. The Jersey and Guernsey breed societies have recognized the importance of fat tests for many years, and have maintained breeds remarkably efficient in fat production.

Cranfield (*J. Agric. Sci.*, xvii., p. 62, January, 1927) has paid special attention to the solids-not-fat content of milk, and shows that a proportion of cows produce milk of remarkably poor quality in this respect. In addition to research work which is being carried out on this subject, it is receiving special consideration by a committee of the Ministry of Agriculture.

Interpretation of Milk Records—Two methods of stating a milk record are commonly used in this country: the "yearly" yield as used under the scheme of the Ministry of Agriculture, the year commencing on October 1 and ending on September 30; and the "lactation yield," which states the yield from the time of calving to the date of going dry.

The simple statement of the quantity of milk yielded during either of these periods does not give a complete picture of the milk-yielding capacity of a cow, and additional data are necessary, as well as a

DAIRYING (*Continued*)—

knowledge of the causes of variations in milk records, in order to assess the production value of a cow.

A fairly complete statement of production may be made by stating the age of a cow at her first calving, every date of calving, the total milk given during every lactation, together with the number of days "in milk" and "dry" during each lactation. The breeder who is using his records as a basis of selection in his own herd usually uses all these data, but there is a tendency, when it is desired to emphasize the merits of any particular animal or breed, to state certain sections rather than the lifetime records of cows, and when this is done an inaccurate impression may result.

Of the work which has been done to improve the interpretation of milk records, special mention may be made of Gavin (*J. Agric. Sci.*, vol. v., part 4), who realized the practical need of estimating the producing ability of heifers at an early stage; also the work of Sanders, who has calculated standardized corrections (*J. Agric. Sci.*, vol. xviii., p. 250, April, 1928) which may be applied to lactation records in order to eliminate the effects of certain factors. The items which may be corrected by Sanders' tables are month of calving, length of service period (time between calving and effective service), age of the cow and length of dry period preceding a lactation.

The degree of the efficiency of milking, feeding, and other management has a marked influence on milk records, and while it is difficult to evaluate these items by correction factors, a knowledge of the management under which a record is produced can assist greatly in estimating its true value.

HOUSING OF DAIRY CATTLE—**Cows**—It is not possible to lay down a general method of housing cows suitable for all farms, and there is little doubt that, if dry, well-drained land provided with sheltering fences or woods is available, cows are healthier if left in the open. This is possible on many farms in the southern parts of England, and under these conditions the only housing required is a simple type of milking shed or the open-air cowshed of the type introduced into Wiltshire by Hosier (*J. Farmers' Club*, part 6, November, 1927). By far the most common system of housing cows in this country is in a cowshed where the cows are tied up, rationed and milked, and remain indoors, at any rate by night, during the winter months. The *Ministry of Agriculture* Miscellaneous Publication, No. 40, 1924 ("The Construction of Cowsheds"), gives a good general survey of the subject, together with plans of typical cowhouses. Also, Major Maule ("The Planning and Construction of Cowsheds," *J. Min. Agric.*, vol. xxix., July, 1922) raises many points of value.

The chief requirements of the Milk and Dairies Order, 1926, regarding cowshed construction, are that there shall be adequate light and ventilation, good artificial light, and suitable and impervious floors and gutters of a material such as rendered concrete. There is a variety of means of tying cows, it being usual to employ chains or a tubular yoke type of fastening; the former gives cows more freedom in moving

DAIRYING (*Continued*)—

forward and backward, which is a disadvantage from the point of view of cleanliness, owing to fouling of the bedding, but the extra freedom is often desirable for heavy milkers or older and less active cows. The advantages of the tubular yokes include cleanliness and a saving of time in tying and untying cows. In general, both means of securing cows are quite satisfactory if properly arranged, and the choice between the two methods is largely a question of deciding whether comfort of the cows or cleanliness and time saving is more important.

Bull Pens—It is only by satisfactory housing and management that a bull can be kept sufficiently long to prove his value for breeding dairy stock; for this reason alone the subject is important. A bull pen should not be isolated, but other animals should be visible at all times, since other bulls, cows, or horses help to interest a lonely animal. A satisfactory bull pen consists of a strongly built house about 12 by 16 ft., provided with a means of catching and securing the bull, with an exercising yard attached. The size of the exercising yard should be as large as possible, but 100 by 20 ft. may be regarded as reasonable. Among various forms of exercisers for bulls described in an article in "Hoard's Dairyman," January 15, 1928, is a mound of earth 4 or 5 ft. high in the middle of the exercising yard; the bull goes up and down this mound to view his surroundings and gets exercise thereby. Good plans of a bull pen, yard, and breeding rack are given in the *University of Missouri Bull.* 275, October, 1929, "Care, Feeding, and Management of the Dairy Sire."

WASTAGE OF DAIRY CATTLE (Common Diseases)—The cost of depreciation of cows is not usually a large item in the cost of milk production, but it depends very largely on the average productive life of cows in a herd and their value on disposal. The presence of disease in a herd can greatly increase depreciation costs, and data has been and is being collected to discover the relative importance of different reasons for the removal of cows from herds. Mackintosh reviews the subject in "Agricultural Research in 1928," p. 35, *R.A.S.E.*, and quotes work which suggests that the average milking life of a cow is about four years.

There are three diseases of dairy cattle which cause considerable losses—tuberculosis, abortion, and mastitis—and since success in the management of a dairy herd depends to a large extent in avoiding these troubles, a few notes on each disease are given below.

Tuberculosis—This disease is very common among dairy stock, and the failure of curative treatment has led to the concentration of attention on other means of control. Many attempts have been made to render animals immune to the disease, and the recent work of Calmette and Guerin has drawn attention to the possibilities of this method. No practical solution along these lines can be offered at present, however, and McFadyean ("Agricultural Research in 1928," p. 163, *R.A.S.E.*) summarizes some of the experiments carried out to test the value of B.C.G. vaccine. He shows that many years must elapse before such a method can be recommended for general adoption, and

DAIRYING (*Continued*)—

in any case the results of trials have thrown some doubt on the reliability of the method.

The Tuberculosis Order, 1925, gives sanitary authorities some control over the milk supply in respect of tuberculosis infection, but probably the order was never intended as an effective means of combating the disease.

The Milk (Special Designations) Order, 1923, provides an incentive to a proportion of farmers to keep herds free from tuberculosis, and the Ministry of Health lay down special regulations governing the means by which herds shall be kept free from the disease.

The only effective control at the present time centres round the use of the tuberculin test with removal or slaughter of reacting animals, and it is possible, by the careful use of these methods, to keep a herd free from this disease. The tuberculin test is sometimes criticized as being liable to give a wrong diagnosis, but the chief criticism which may be brought against the test is that in common with most biological tests it is capable of misinterpretation and misuse. The abuse of the test is more likely to be practised among animals which are being placed on the market, and under these circumstances its reliability may be impaired. When used as a genuine means of detecting tuberculosis within a herd, the test is capable of yielding excellent results.

A few countries, including Canada and the United States of America, have adopted comprehensive schemes for the eradication of tuberculosis from cattle. Financial assistance is given for carrying out the tuberculin test and compensation paid for reacting animals; when possible all the cattle within large areas are dealt with collectively, and all reactors removed. (See Hilton, "Control of Bovine Tuberculosis in Canada," *J. Dairy Res.*, vol. i., No. 1, p. 58.)

Schemes based on similar lines are receiving attention in Scotland; in one area the farmers are co-operating with the Hannah Dairy Research Institute in an attempt to eliminate tuberculosis from their herds, and a more general scheme which is under consideration is published in the *Veterinary Record*, September 21, 1929.

Abortion—The type of abortion due to bacterial infection is widespread in this country, and causes considerable loss to the dairy industry. Until quite recently the only persons particularly interested in the disease were farmers and veterinarians, but since the discovery of the close connection between the abortus bacillus and the organism causing Malta or Undulant fever, the interest in the disease has become much more widespread. In a "Review of Undulant Fever" (*J. Dairy Res.*, vol. i., 2, p. 180, May, 1930) Mills reviews the literature, and shows the connection between Bang's bacillus, Malta fever, and Undulant fever; also McFadyean ("Agricultural Research in 1928," p. 172, *R.A.S.E.*) gives useful information on the same subject. One means of dealing with the disease is the immunization of animals by the use of a vaccine; this method is not recommended for general adoption, but is mentioned in the *Ministry of Agriculture Leaflet* 108, and may be of value in herds which are maintained by purchased

DAIRYING (*Continued*)—

stock, or where the disease is particularly active. When using a vaccine which contains living bacilli, it will be obvious that disastrous results may follow, unless great care is exercised in carrying out the instructions issued with the vaccine.

In herds which are not badly infected, the most satisfactory means of control is complete elimination of the disease; the agglutination test being used as a means of discovering infected animals. When this method is practised, it is necessary to isolate infected animals and exercise great care to avoid the spread of the infective organisms, while an abortion-free herd can only be maintained by immediate isolation and blood testing of animals which abort, and introducing only non-infected animals into the herd.

The Epizootic Abortion Order, 1922, regulates the exposure in sale yards and other movements of cows which have aborted.

Mastitis—The term mastitis, mammitis, or garget, is used to indicate certain diseases of the udder usually characterized by the secretion of abnormal and often clotted milk, also a hardening and inflamed condition of one or more quarters. The condition may be due to a variety of causes, and while certain forms of the disease are fatal, the usual result is the loss of affected quarters and consequent reduction in milking ability; for this reason it is very desirable to concentrate on preventive rather than curative measures.

Prevention may be considered under two heads:

1. *Avoiding Original Infection of the Udder*—Perhaps one of the most important points in this connection is by preventing injuries to the udder, due to such causes as rough milking methods or rapid walking by heavy milking cows. Anything which damages the udder tissue appears to encourage mastitis infection, and overstocking, irregular milking, and improper drying off of cows are to be condemned.

2. *Immediate Isolation and Treatment of the Disease*—A few cases of the disease occur in most herds, and it is most important to diagnose the trouble at an early stage in order to avoid the spread of disease to other cows. Infection occurs through the teat orifice, or possibly through sores and abrasions on the teats, so that there are many opportunities of the infective organisms being passed from cow to cow during the milking process. Cows suffering from the disease should be washed with separate cloths, milked last, and the milk never drawn on the floor of the cowshed where another cow may lie down and become infected.

The most effective treatment which the farmer can apply is milking at frequent intervals and gentle massage of the udder.

Useful notes on the disease are given by McFadyean (*loc. cit.*) and by Minett (*Eleventh Inter. Vet. Cong.*, London, 1930).

MILK SECRETION AND MILKING—The udder of a cow consists of four glands or quarters, each of which functions separately, and has a teat with an external orifice connected with a cavity or milk reservoir, from which ducts spread to all parts of the quarter rather like the

DAIRYING

branches of a tree. These ducts subdivide and finally end in small sacs or alveoli, where the secretion of milk takes place.

Milk is elaborated from the blood in the secreting cells of the udder; it escapes from these cells and passes from the alveoli down the small ducts in the udder and gradually fills the milk reservoirs.

Thus, in the udder of a cow just before milking, the portion of milk which fills the milk reservoirs and larger ducts is only retained in the udder by the sphincter muscle at the end of the teat, and this milk is easily removed by the normal milking action. The quantity of milk in the milk reservoirs, however, is small compared with the amount contained in the very small ducts, alveoli, and cells of the udder; this portion of the milk cannot be expressed by purely physical force, but is subject to control by the nervous system of the cow, and may be withheld at milking time.

The quantity of milk obtained from a cow, therefore, depends not only on the secreting activity or the milk-making efficiency of the glands, but also on the proportion of the secreted milk which is withdrawn during the process of milking.

Secretion—The actual secretion of milk in the lactating cow is considered to be a continuous process between milkings, the speed slowing down as a result of the accumulation of milk in the udder. It has been calculated that the secretion during any given hour between milkings is about 95 per cent. of the previous hour's secretion, and this rapid secretion in an udder which has just been milked accounts for the increased production resulting from thrice daily milking.

There are, of course, many other factors which influence the rate of secretion of cows, such as feeding and management, age of the cow, stage of lactation, efficiency, and health of the mammary gland itself.

Little is known as to the quality of milk secreted by the cow from hour to hour, and the results of experiments on the subject are conflicting. It is known that the composition of milk changes when a cow is not milked for very long intervals; for instance, the lactose content is reduced and chlorides and the ash increase, but for cows milked at regular intervals it is more probable that milk as secreted is fairly constant in composition for each cow.

Milking—The udder of a cow immediately after an efficient milking still contains a small quantity of milk, but the aim in milking should be to reduce the quantity retained in the udder to the lowest possible amount. Hammond was able to obtain appreciable quantities of milk from goats just after milking as a result of the injection of pituitary extract, and the most simple explanation is that the extract caused a complete emptying of the glands. During normal milking this milk is expressed from the cells and small ducts by a contraction of the udder, believed to be brought about by the voluntary action of the cow. Anything which disturbs or checks this action after it has commenced reduces the effect, and makes complete removal of the milk impossible. For this reason it is most important that nothing should occur at milking time which is likely to give the cow any cause for

DAIRYING (*Continued*)—

fear, or any unusual interest other than the milking process. Some cows are naturally more nervous than others, and milkers vary temperamentally as well as in efficiency, and the interaction of these influences result in slight differences in the completeness of milking from day to day.

There are two important reasons why milking should be thorough; the first is that milk left in the udder tends to reduce secretion and causes the cow to dry off too quickly, and the second that the strippings from a cow are very rich in fat, so that incomplete milking reduces the quality as well as the quantity of milk yielded.

Hand Milking—It is usual at the present time to regard the cleaning of the cow as an essential part of the milking process. The chief essentials are that cows should be washed, not dry groomed, particular attention being paid to the udder, teats, and parts of the flanks most likely to cause contamination of the milk. The first few draws from each teat should be rejected, since the orifice of the teat often contains dirt or germs which cannot be removed by the ordinary washing of the teats. Milking should be carried out by grasping the teat with the full hand, the milk being drawn by a squeezing action, avoiding a pull or jerk on the teats. Rough handling may damage the tissues of the teat and be one cause of the formation of swellings, or peas as they are sometimes called. Wet-hand milking is a dirty habit, especially where the teats and hands are not thoroughly washed; the general opinion at the present time is that dry-hand milking is much more cleanly, and with a little practice can be just as efficient; for this reason persons learning to milk should commence and continue by the dry-hand method.

Machine Milking—The fact that two makes of milking machines have already been awarded certificates by the Machinery Testing Committee of the Ministry of Agriculture is proof that these machines are capable of efficient work.

The production of milk of low bacterial content by means of milking machines (Mattick and Procter, *J. Hygiene*, vol. xxvii., p. 215, January, 1928) shows many interesting points in connection with milking machines, not the least being that the rubber parts of the machines withstood regular sterilization by steam. The importance of proper sterilization is also shown in "Studies concerning the Handling of Milk" (*Third Ed. Res. Monograph*, No. 1, *Min. of Agric. and Fisheries*, p. 23). While machine milking can be highly satisfactory, the results of improper use are perhaps more disastrous than inefficient hand milking; for example, if the machine is left on a cow for longer than is essential, it tends to decrease the rate at which milk is given down, and therefore reduces the speed of milking; careful washing is needed, since there are many parts in the machine which are somewhat inaccessible; also the small amount of milk which is seen by the milker makes it most important that fore milk and strippings should be observed carefully in order to note the presence of mastitis at an early stage and prevent it spreading through the herd.

DAIRYING (*Continued*)—

CLEAN MILK PRODUCTION—The cleanliness of milk production has improved considerably during the last few years, resulting in better keeping qualities of the milk and less trouble with taints and bad flavours, while the production of a more reliable and marketable milk must tend to increase the consumption.

The Milk and Dairies Order, 1926, imposes a system of licensing on milk producers, and regulations are laid down as to certain methods used for milk production and handling. This order enforces reasonably clean methods, but most of the improvements to date have been effected by educating producers and consumers in the advantages of a better milk supply.

A scheme for encouraging cleaner milk production by purely voluntary means is the Milk (Special Designations) Order, 1923, which permits milk producers who comply with certain regulations as to the health of their cows, and cleanliness of the milk produced, to use distinctive designations for their product, such as "Certified" or "Grade A (T.T.)" milk. Other milk producers are not allowed to use these special terms, and producers of these grades of milk may, and usually do, obtain a better price for their product.

Other means of encouraging clean milk production are Clean Milk Competitions that are organized by a large number of counties in England and Wales (see "Studies concerning the Handling of Milk," *Min. Agric. Res. Monograph,* No. 1, p. 33); also many milk depôts when buying milk pay a bonus for cleanliness.

To the milk producer who desires to improve his standard of cleanliness, the essentials of clean milk production may be learned, perhaps, most quickly by entering a county clean milk competition, and an excellent incentive to regular good work is the payment of a bonus to cowmen based on the cleanliness of the milk produced.

Taints and Flavours—The presence of substances in milk which give bad flavours may originate from the cow through the secreting system, or the milk may become contaminated later by the direct addition of tainting substances, or by the production of these substances in the milk by bacteriological or chemical action.

Taints occurring before the milk has left the udder are usually due to the food of the cows, and such plants as garlic, stinking mayweed, and, to a less extent, kale, and turnips, often produce abnormal flavours in milk. The cure for such taints is the removal of objectionable weeds from the diet or the feeding of such foods as kale in moderate quantities immediately after and not before milking. The transfer of flavours from food to milk through the blood stream seems to vary in different cows, and there is little doubt that a taint may be present in the udder soon after feeding certain foods, but may disappear after a few hours. Apart from the influence of food, certain cows, especially those in an advanced stage of lactation, may secrete milk with an abnormal flavour or containing enzymes capable of producing taints.

Bacteria are capable of producing a great variety of taints in milk,

DAIRYING (*Continued*)—

and the solutions to most of the resulting troubles in this respect are a good water supply and the practice of the principles of clean milk production, including sterilization of milk utensils.

The action of metals in producing undesirable flavours in milk has been shown to be important; thus Mattick ("Oiliness in Milk," *J. Agric. Sci.*, vol. xvii., 3, 1927) describes an oily flavour produced by a chemical action which is accelerated by the presence of minute quantities of certain metals, especially copper. This point is important and shows the necessity of using coolers, strainers, and other utensils on which copper surfaces are thoroughly tinned to avoid direct contact with the milk. (See also Davis, "Milk and Metals," *Agric. Progress*, vol. vii., 1930.)

Valuable notes on this subject are given by Mackintosh in *Agric. Res.*, p. 52, 1926, and p. 47, 1928; also by Rogers, "Fundamentals of Dairy Science," p. 321 (Chemical Catalogue Company, N.Y.).

S. B.

"DAMPING"—In physics any agency which offers resistance to sudden motion of a body is said to "damp" its motion; most usually the term is applied to periodic vibrations of a body, such as those of a pendulum, which may be damped by immersing the end in oil, or the small erratic movements of a volt-meter needle, which may be damped out by eddy current effects in a soft iron core to the coil. The chief example, from the agricultural point of view, is doubtless the use of the dash-pot type of shock absorbers in machinery.

DAMSON—See Stone Fruit, under Fruit; for methods of preservation by refrigeration see Refrigeration.

DARI—For feeding value see Feeding Stuffs, and Poultry, Nutrition; also Agriculture, India.

DATES—For methods of preservation by refrigeration see Refrigeration.

DEW—The deposit of moisture which appears on the leaves of low-growing plants and indeed on any good radiating surface not too far from the ground. If the conditions are such that the deposit is made directly from the water vapour in the atmosphere to the solid phase (ice), the deposit is known as hoar-frost. (See Dew Point.)

It is worth noticing that the deposition of dew is to some extent a protection for the plant against frost, as the whole of the latent heat of vaporization of the water is liberated on and in the neighbourhood of the plant leaves as the condensation proceeds, and this is equally true with the added amount of the latent heat of fusion when the deposit is in the form of hoar-frost. (See Heat, Latent; also Meteorology.)

DEW POINT—The temperature to which the air must be cooled in order that it may be saturated with water vapour. When this temperature is reached, other things being suitable, dew will be deposited, but it is in the further particularization of the meaning of "other things being suitable" that the interest of the matter chiefly lies. Aitken

DEW POINT (*Continued*)—

showed as early as 1885 that the favourable conditions are (1) a good radiating surface, (2) a still atmosphere, (3) a clear sky, (4) thermal insulation of the radiating surface, and (5) warm, moist ground or some other provision to produce a supply of moisture in the surface layers of air. The last condition shows why dew is usually deposited chiefly on the underside of grass leaves, etc. If the only source of dew were the moisture actually in the air, only a little could be deposited, as the supply in the neighbourhood of the object would be narrowly limited. Aitken showed, however, that a process of continuous distillation goes on in the layer of air within a few inches of the ground, the temperature of which is, under these conditions, higher than that of the air and plant leaves just above it. It is, moreover, certainly true that in many cases some of the apparent "fall" of dew has actually been exuded from the plant tissues themselves which have been actively transpiring up to the moment of sundown. This is most noticeable in our climate in the case of the Tropæolaceæ.

The total annual amount of dew deposit is considerable, attaining the equivalent of about 1½ ins. of rain in this country and considerably more in the tropics, where certain xerophytes receive almost all their supply of moisture in the form of dew, which they have special means of absorbing and storing up.

For determination of dew-point see Hygrometer.

DEW PONDS—Isolated ponds found on the upper levels of the chalk downs in Southern England and elsewhere, often used for watering cattle. They have been known from neolithic times, but the dew fall really makes very little difference to them, rain and surface water being their principal source of supply. It is said that the water will not accumulate unless some is first placed in the basin, after which the pond maintains itself. The full theory of their maintenance is little understood. Hall and Russell ("Agriculture and Soils of Kent, Surrey, and Sussex," p. 98) state that they are usually found set back a little from the escarpment, and that the bottoms consist of puddled clay. They suggest that one of the sources of their water may be sea fog condensed on foliage which normally overhangs them. The temperature about them is also often lower than at other places round about in less exposed situations. E. A. Martin ("Dew Ponds," London, Werner Laurie, *circa* 1910) describes many experiments carried out by himself, as the result of which he concludes that sea fog has much more to do with their replenishment than any other source, many ponds having no overhanging vegetation, the chief evidence for which conclusion is the large percentage of sodium chloride found in the water.

DIALYSIS—A process for the separation of *crystalloid* from *colloid* substances, discovered by Thomas Graham in 1862, and not much changed since then. If an aqueous solution containing, say, sugar and gum, is placed in a vessel, the bottom of which is of parchment, and this vessel is then floated on the surface of pure water, it is found that in time the sugar passes through the parchment, while the gum does not; if the process is allowed to proceed to completion, the sugar concentra-

DIALYSIS (*Continued*)—

tion will eventually be sensibly the same inside and outside the vessel, and if arrangements are made to renew the water outside as the sugar passes through, a complete separation of the sugar from the gum may be effected. The process has long been used in the filtration of molasses. Instead of parchment, fish bladders and collodion membranes are largely employed. Zsigmondy and Heyer have designed an apparatus for rapid dialysis, in which a thin radial stream of water is kept flowing from the centre of the membrane to the circumference. Collodion membranes for dialysis may be made by dissolving 25 gm. of collodion wool in alcohol sufficient to cover it, and then making the volume up to 1 litre with ether. A glass vessel of the required shape is then selected and dipped in the solution, dried, again wetted with water, dipped in the solution a second time, and so on. In this way a membrane may be built up of any desired strength. For milk filtration a membrane with comparatively large pores will be found sufficient.

DIASTASE—An enzyme developed in seeds during germination, possessing the power of transforming starch into sugar (maltose). It can be precipitated in powder form from malt extract, and retains its amyloclastic power. The so-called "diastatic power" of a sample is estimated either by the amount of maltose produced in a certain time, or by the time taken for a known amount to convert a standard starch solution into products which do not give a blue colour with free iodine. It is more or less identical with the amylase of the pancreas and with taka-diastase produced by the action of *Aspergillus oryzæ* on rice. The latter is a very powerful amyloclastic ferment.

In the manufacture of beer, diastase plays an important part in the early stages of the production of the fermentable liquor. After steeping the barley for some hours, it is spread out on the floors of the malt house and the grains germinate. During this time an enzyme named cytase is liberated, which attacks and dissolves the walls of the cells containing the starch granules. When this is accomplished further enzyme action is stopped temporarily by kiln-drying the grain. The malt, as the grain is then called, is next digested with water of varying degrees of temperature in a mash tun, and it is during this time that diastase is liberated and attacks the starch granules, transforming them into sugar-maltose.

DIGESTION—Apart from an unimportant application of the term in chemistry, and the case of insectivorous plants such as the sundews, nepenthes, sarracenias, etc., when we speak of digestion we mean the whole process by which animals in general dispose of the food they eat. From the point of view of the agriculturist, we may confine our attention to the higher vertebrates. There is a tendency to stress the differences in the digestive apparatus of vertebrates of various kinds, and while this is quite necessary where veterinary or metabolic studies are in question, it may well be deemed desirable in a short article to lay stress rather upon the similarities. As between the different genera of mammals this is easy, and it will not be difficult to connect up the corresponding processes in birds.

DIGESTION (*Continued*)—

Shortly then, the alimentary canal consists of a long tube with numerous wider portions through which the food passes, and in so doing is exposed to the action of digestive juices of various kinds depending for their action on enzymes. It may be divided into three main divisions: (i.) a comminative region in which the food is broken up and ground to a pasty consistency, being at the same time mixed with certain digestive juices; (ii.) a resorptive region in which the main digestive action takes place; and (iii.) a region in which the action of bacteria is brought to bear on portions undigested higher up, and into which the body excretes a certain amount of poisonous material which would otherwise have to be dealt with by other excretory mechanisms. Towards the end of this the solid fæces are formed.

In mammals the first region comprises the buccal orifice, in which the act of mastication serves to break up the food and mix it with the secretion of the salivary glands which contain ptyalin, an amylase whose function is to begin the conversion of starch into sugars. When the food has been sufficiently chewed, it passes by way of the œsophagus to the stomach in carnivora, and there it is mixed with the gastric juice containing a digestive ferment, pepsin, which is activated by the hydrochloric acid also secreted there. Pepsin initiates the digestion of proteins. In ruminants the process is essentially similar, the true stomach being the abomasum, in which alone gastric digestion takes place. In these animals most of the very imperfectly masticated food passes to the rumen or paunch and the reticulum, which are really special enlargements of the œsophagus, only the finest material passing by way of the manifolds to the true stomach. In the paunch, which is very large, the food remains in contact with moisture and ptyalin, and with some bacteria which initiate the digestion of crude fibre until it is regurgitated to the mouth and mastication completed in the process of "chewing the cud." It is then again swallowed and now most of it passes through to the abomasum. The stomach in the horse and the pig, each of which consumes some quantity of fibre, the former a great deal, the stomach is not quite simple as in carnivora, but shows division into three regions known as the cardiac, fundus, and pyloric, but in these creatures the ruminant habit has not developed, and the fibrous material is otherwise dealt with. Birds having no teeth, swallow their food whole and store it in the crop, where it remains in contact with softening juices until it is passed to the ventriculus or stomach, in which it is mixed with other digestive juices and pulped by means of the gizzard, which constitutes a part of the ventriculus.

Ptyalin is absent from the saliva of carnivora, and it has been shown by Lovatt Evans that the amount secreted in man depends upon the carbohydrate content of the food being chewed. The action of ptyalin is stopped by the hydrochloric acid in the stomach, but its action is more prolonged than might thus be imagined, as Grützner has shown (*Pflüger's Arch.*, 106, 463, 1905) that the food in the stomach only gradually comes in contact with this acid owing to its pasty consistency.

DIGESTION (*Continued*)—

So far no absorption of the products of digestion has taken place; it is singular that this should be so, and perhaps the reason is to be sought in the fact that with the exception of small quantities of sugars, no part of the food has yet been split up into very simple molecules.

Passing now to the second portion of the alimentary tract, which is devoted to resorption, the small intestine, this is usually divided into three parts—namely, the duodenum, the jejunum, and the ileum, the last two being indistinguishable from one another in the fowl, while in other animals it is largely a matter of position. The comminated and partially digested food, known as chyme in animals, passes from the stomach to the duodenum a little at a time by way of the pylorus, a sphincter which closes again as soon as the hydrogen ion concentration has risen above a certain point on the duodenal side. In the duodenum the food is mixed with bile from the gall bladder and liver, and the digestive juice from the pancreas, which contains trypsinogen, a zymogen requiring activation by the enterokinase of the succus entericus secreted by the glands in the walls of the duodenum and small intestine. The activation of the trypsinogen gives rise to trypsin, a powerful proteoclastic enzyme acting also on peptones which are present in the results of gastric digestion, with formation of amino-acids. Any lower products of protein digestion, such as the lower peptides, proteoses, and peptones, are powerfully attacked by erepsin, another constituent of the succus entericus which contains also invertases (maltase, sucrase, lactase, etc.), which completes the breakdown of starches to monosaccharides, and agents for splitting up nucleo-proteins. Bile is a solvent for free fatty acids, and both the pancreatic juice and the bile combine to ensure the digestion of fats, the former by supplying the enzyme steapsin, which saponifies the fat, the latter by its solvent action as indicated and by facilitating emulsification by its power of reducing surface tension. The final products are thus fatty acids and glycerol from fats, amino-acids chiefly from proteins, and monosaccharides from starches, sugars, and other carbohydrates.

These products of digestion are absorbed, or, as it is often called, "resorbed," by the cells of the folds or villi of the interior surface of the small intestine, and conveyed thence to the blood stream direct (except fat) by the walls of the capillary arteries and veins with which these villi are abundantly provided, and pass thence with the blood to the portal vein. Fats behave in a curious manner, since the glycerol and fatty acids recombine in the epithelial cells of the villi to form fat globules again, and these pass to the lacteals of the villi and so by the lymphatic system, till they eventually enter the blood by the thoracic duct. It is these small globules of fat which constitute the so-called "blood-dust" seen under the microscope.

From the ileum the remaining contents of the small intestine pass to the third region, comprising the cæcum (two in the fowl), colon or large intestine, and rectum. The cæcum is a seat of intense bacterial action, and in the horse is of large size to deal with the considerable quantities of fibre which in other herbivora are largely

DIGESTION (*Continued*)—

broken down in the paunch; it is a blind diverticulum of the colon. The colon of the horse is also exceptionally voluminous, and whether in this or other animals is the seat also of considerable supplementary resorption, although not provided with villi. Water is largely absorbed by all parts of the last two regions, especially the latter part of the colon.

The digested matter is forced along the intestines by a rhythmic motion of the walls called peristalsis, caused by the passage of successive waves of constriction along the tube from the pylorus toward the rectum. Where matter passes from the colon into the rectum, the desire to defæcate arises and evacuation of the lower bowel then takes place.

It has been mentioned that the third region is also a seat of normal bodily excretion, as is seen by the fact that an empty loop of the intestine, separated by short circuiting and tying from the rest of the bowel, rapidly fills with fæcal matter.

The processes of resorption, while doubtless helped at times by osmosis, are really vital phenomena of the life of the cells of the epithelia of the villi, as they take place from isotonic solutions of amino acids, sugars, etc.

Digestion is treated from the agricultural point of view in Armsby, "Nutrition of Farm Animals," chap. iii. (New York, 1917). A more advanced treatment of general problems concerned will be found in W. M. Bayliss, "Principles of General Physiology," pp. 299-376 (Longmans, London, 1920), and of processes in E. H. Starling, "Principles of Human Physiology," pp. 706-838 (Churchill, London, 1920).

DIGITALIS—A preparation of the leaves of the foxglove, *Digitalis purpurea* (Scrophulariaceæ), gathered when about two-thirds of the flowers are expanded. It is a strong cumulative poison with a distinct cardiac action prolonging diastole, thus affording the heart muscles opportunity for rest and recuperation. It is also a powerful diuretic. The active principles are digitoxin and digitalin—two glucosides, of which the former is said to be the more active.

DISEASES, PLANT—For Diseases of Cereals see article at conclusion of Wheat; Diseases of Forage Crops see article at conclusion of Legumes, Breeding of Forage; Diseases of Glasshouse Crops, see Glasshouse Crops; Diseases of Hops, see Hops; Diseases of Potatoes, see Potato; Diseases of Vegetables, see individual vegetables under Market Gardening; also see Seed, Transmission of Plant Diseases by; and Plant Diseases and Pests, Legislation with Reference to; Plants, Disease in, Resistance to; Virus Diseases.

DISTILLERS' GRAINS—For composition and feeding value see Feeding Stuffs.

DODDER CLOVER—See Seed, Transmission of Plant Diseases by; also Seed, Testing (Official) Regulations as to.

DRAIN GAUGES—See Lysimeters.

DRAINING—Although draining has been an agricultural practice for a great many years, it is one which is still imperfectly understood by many agriculturists. Indeed, it is probably true to say that less is generally understood now than in the middle of the nineteenth century when very large areas in Britain were being drained. In any case the subject is difficult because most of the work is below ground, and because any faults in execution may become apparent only after the lapse of five, ten, or even twenty years. Even with the comparatively simple surface draining, the knowledge possessed by many seems to be scanty, or at least seldom applied, judging by the condition of many farm roads and farmyards.

Perhaps the best introduction to the subject of this article can be obtained by studying the fate of rain which falls upon dry land in the autumn months. The first rain during this period is absorbed by the soil itself; some may be evaporated; if the land is occupied by a growing crop some will be taken by the roots and evaporated through the leaves in the ordinary way. When more rain falls it sinks farther into the soil, moistening the deeper layers as it percolates, until at length it reaches an impervious layer of the soil, or the water table above this layer. If more rain now falls and sinks into the soil, the interspaces between the soil particles become completely filled with water as the water table rises. From this point two alternatives are possible in the natural state, either a stratum of soil above the impervious layer is found to be porous and able to facilitate the lateral flow of water below ground, or the water table rises until it reaches the surface, and the land becomes waterlogged. In the former case the lateral passage of subsoil water below ground carries the water away until it is discharged in the form of a spring, into a stream or river and thence into the sea; or the porous layer brings it to the surface at a lower level, causing swampy land. In the latter case the water runs over the top of the waterlogged land until it in turn finds a ditch or other channel for its ultimate discharge into the sea. The former is a case of natural underdraining, the latter of natural surface draining.

Artificial draining is carried out for the purpose of facilitating the draining of water from land which would otherwise become waterlogged.

Systems of Draining—These may be considered under four headings: First, there is surface draining, which provides for the removal of water above ground by the aid of open channels. Secondly, in point of historical application, there is Elkington's system, or spring tapping, a system which aims at trapping the underground watercourses previously mentioned.

Thirdly, underdraining, a system by which artificial underground channels are provided for collecting and transporting the water below ground, just as a porous layer provides for natural underdraining; mole draining is a part of this system.

Lastly, arterial draining, or the removal of water from large marshy areas, such as the Fenlands of East Anglia, by the help of engineering works, pumps, etc. This is the province of the engineer rather than the agriculturist, and will not be further discussed here.

DRAINING (*Continued*)—

Surface Draining is both very simple in its application and inexpensive in execution, but nevertheless repays careful planning before execution. It is designed to deal only with surface water, and to remove this rapidly through wide open channels. Two guiding principles should be kept constantly in mind: the action of gravity, and the inclined plane. With these in mind it is astonishing to what extent surface draining can be applied usefully on the farm. Provision must always be made for the ultimate discharge of the water, and, so far as possible, for a regular fall in the drainage channel. With an irregular fall there is liability of washing away of the soil where the gradient is steep, and silting up of the channel where the gradient is flat.

The first illustration of surface draining may be taken from farm roads, especially those about the farmyard and stackyard. The roads should be highest in the centre with definite channels at the sides; the open spaces about a farmyard should be graded to a channel at the lowest side, and this, in its turn, provided with an outlet for the discharge of the water. Such grading can be quickly and efficiently accomplished by the help of a horse-shovel, an implement common in colonial farming, but, unfortunately, little known in Britain.

Another application of surface draining is that of drawing water furrows on retentive arable land before or after the crop is planted. These furrows should be drawn with the plough along the line of the lowest slopes, with outlets provided into the nearest ditch.

In some cases, especially in large fields with long continuous slopes, it may be desirable to draw other furrows diagonally across the slope, each furrow provided with a slight but continuous fall; such furrows tend to trap the rain water as it seeps down the slope of the field, travelling mainly just above the subsoil.

The stetch-land system of farming, so commonly seen in Essex, is a specially refined form of furrow draining. In this the fields are ploughed into very narrow lands, called "stetches." The crop is planted only on the lands, the furrows being kept clear to provide drainage of the surface water.

Surface draining is also used in woodland, where tree roots tend to block or disturb drain pipes, and on hill pastures in rainy districts, in which case the shallow drains are led round the slopes of the hill so that too steep a fall in the drain, with its tendency to wash out, is obviated. It is also used on low-lying meadows in valleys which are liable to flooding. In this case the V-shaped section of the open drain provides for the rapid evacuation of the flood water.

Elkington's System or Spring Tapping was, as its name suggests, the system elaborated by Joseph Elkington in the latter part of the eighteenth century, and consists of locating the underground paths traversed by subsoil water, and then tapping and diverting this flow so as to prevent its issuing to the surface farther on, thereby causing bogs and swampy land.

This system provided a method of draining large areas of land by means of carefully placed, deep ditches, long before underdraining was seriously thought about in this country. Such drains or ditches

DRAINING (*Continued*)—

continue to operate efficiently at the present time, when kept open properly, although relatively few agriculturists recognize them when they see them. Nevertheless, after wet weather, in many ditches cut at right angles to the slope of the land, water may be seen weeping out of a porous layer in the bank of the ditch, or gushing up as a spring from a similar porous layer below the floor of the ditch.

Elkington's system of draining, therefore, refers only to the drainage of subsoil water. It is not concerned with the removal of surface water. Before bringing this system into operation a most careful examination of the subsoil, and especially the porous layers, must be made; the main springs must be located and the cause of wetness clearly ascertained before planning the remedy. In one of the most typical and simplest cases it may be found that water falling on high ground has percolated through porous layers to the lower slopes, where it is caused to come to the surface by an impervious layer. The lowest points on the slope reached by the porous layer are located. Along the line of these points, or slightly above them on the slope, a deep ditch is dug more or less at right angles to the slope. If the bottom of the ditch taps the porous layer, water will flow into the ditch from which it is led to the river or stream in the valley by other ditches running down the slope. If the porous layer is below the floor of the collecting ditch, bore holes may be made through the floor of the ditch to the porous layer below. When the porous layer is reached the water will be forced therefrom, through the bore holes, by the pressure of water from the higher levels of the slope.

This illustrates one out of many applications of spring tapping; fuller information about this can best be obtained in "An Account of the Most Approved Mode of Draining Land, by Elkington," written by Johnstone in 1797.

Underdraining, as its name implies, refers to the drainage of water through underground artificial channels, and is intended to deal essentially with rainfall which falls on the area immediately concerned. When this system was first practised, the channels were kept open by hawthorn stems and brushwood, by stones, by chalk, etc.; these were succeeded by drain tiles bent into the form of a horseshoe, then, later, by the same form of tile placed upon flat tiles; finally, circular tiles of various sizes were made, with and without collars, and largely displaced the other materials.

In mole draining, to be discussed later, the channels are kept open only by the retentive nature of pressed clay. During the nineteenth century very large areas in Britain were drained with tile drains, and, where well-executed and well-maintained these still function, but much of this draining has fallen out of repair. At the present time the cost of tiles, and especially of labour, is so high that tile draining is unprofitable except for valuable crops, such as fruit, or for the drainage of small areas in an otherwise well-drained field.

In the past, great controversy arose upon the depth at which drains should be placed; early numbers of the *Journal of the Royal Agricultural Society* provide interesting reading upon this point. Smith, of

DRAINING (*Continued*)—

Deanstone, in Perthshire, about 1840 advocated shallow and frequent drains, whilst Josiah Parkes, the engineer, advocated drains of a minimum depth of 4 ft. placed at wide interfalls, arguing that such would be more permanent and keep the water table lower. Controversy on this point has continued ever since. There can be no absolute answer to the point at issue, and the truth lies somewhere between the extreme views. If the soil is moderately open and porous, the drains may be placed deeper and at wider distances, because water can move both vertically and laterally with greater freedom through such soils. On the other hand, if the soil is impervious, the water does not reach the drains quickly enough. Deep drains are more permanent and less likely to be disturbed by the passage of heavy traffic, tillage implements, or the roots of trees; on the other hand, the cost of digging is greater and the outfall, being deeper, is more likely to be blocked by the silting of neglected ditches. On porous land the best depth is between 30 and 40 ins.; on impervious clay between 20 and 30 ins. For further details about the planning and execution, reference should be made to a standard textbook on the subject.

In some parts of the world, especially America, the manual labour of digging drains has been replaced largely by trench-digging machines, which may be extremely useful especially for the deeper main drains. These machines involve a large outlay of capital, yet, when properly controlled, are capable of expeditious and efficient work.

Mole Draining—In contrast with tile draining this method can be cheaply executed, and, though not applicable to all types of soil nor so durable as the tile, offers good opportunities for draining most types of heavy clay land. This system was first designed for use with heavy steam engines only, such as are used for steam ploughing. Shortly, the system consists of hauling a heavy iron rod, 3 or 4 ins. in diameter, fixed to a suitable framework, through the soil at a depth of between 20 and 30 ins., when it is in a suitable condition to receive the mole, *i.e.*, when the clay is neither too dry nor too wet. In the former case the clay tends to crumble and does not retain the open channel left by the mole; in the latter case the heavy engines cause fearful damage to the fields over which they travel, and the frame carrying the mole tends to cut into the soil irregularly so that a uniform depth cannot be maintained.

Certain definite conditions are necessary for successful mole draining besides the right texture of soil. The field to be drained must have a uniform slope of some considerable extent; land of the hog-wallow type or of mixed irregular slopes is unsuitable, because the mole drains would have the same uneven fall as the surface over which the mole drainer passed. The mole drains must be provided with suitable outlets, so that the water which finds its way into them with great rapidity can be quickly evacuated; nothing prejudices the lasting power of mole drains so much as being allowed to stand full of water for any length of time. In some cases the moles are drawn directly uphill from the bank of the ditch into which they evacuate, but this is not generally satisfactory because the surface of the land near the

DRAINING (*Continued*)—

bank is often irregular, and because the outfalls tend to become quickly blocked. The best plan is to dig and lay a tile drain into which the moles may empty either before or immediately after the moles are made. This should have a relatively large bore, because the moles, if placed close together, as they should be, evacuate the water very rapidly. Provision is made for the water to pass from the moles to the main, either by connecting the end of the mole to the main by a short length of three or four small drain tiles with a proper junction, or by placing a layer of hawthorn bushes or, better still, a layer of clinkers above the main and drawing the mole right through this porous layer. In some cases the main is made with bushes only, or by a cross drawing of the mole, both of these methods are temporary, and not very satisfactory. As previously mentioned the moles should be placed very close together, at distances varying between 6 and 15 ft., according to soil and rainfall.

In recent years mole draining has been practised with direct haulage by tractor power. This has the advantage that the farmer can do the work with his own power without hiring, but generally the work is not so satisfactory as with steam power, because the ordinary light tractor has not sufficient power to haul the mole, even of smaller diameter, at a sufficient depth, and because at the lowest parts of the field, where it is specially important to haul the mole cleanly, the wheels of the tractor are so liable to slip. Caterpillar tractors are best for this purpose, when the surface is wet and slippery. An alternative method, which is now being developed, consists of using the tractor as a stationary engine and operate this through a windlass; this gives satisfactory results because all the power is available for hauling the mole, and the power is just as efficient whether the mole is passing a dry or a saturated part of the field.

The same apparatus can also be used, when attached to a suitable trench cutter, for digging the main drain. Although the windlass method is the most efficient for use with tractor power, the direct haulage of a small mole by tractor is so easy to organize and so cheap to execute, that large areas are being drained each year by this method, and provided the draining is repeated within a few years, the results are generally quite satisfactory.

A. A.

DREDGE CORN AND MASHLUM—The growing of dredge corn, or mixed cereal crops, usually oats and barley, is a fairly common practice on stock-rearing farms in the west of England, particularly in Cornwall and in North Devonshire, where the acreages in 1929 were 41,300 and 12,295 respectively.

The advantages claimed for such a practice are as follows:

1. There is less risk of crop failure by growing two cereals together instead of singly; this applies particularly on the poorer land on which dredge corn is often grown.

2. A heavier yield may be expected, as a larger amount of grain is produced than can be secured from barley alone and very frequently than from oats alone; also, a greater yield of straw of higher feeding value.

DREDGE CORN AND MASHLUM (*Continued*)—

3. There is less risk of the crop lodging in bad weather.
4. A suitable mixture for feeding to cattle and sheep is produced, and there is a saving of labour in mixing.
5. The oat is a deeper rooted plant than barley, so that with the two plants grown in conjunction the lower soil is drawn upon for food as well as the top layers.

The fact that there is less risk of crop failure is probably one of the most important advantages, and it will be found that the districts in which dredge corn is most widely used are those in which cereal growing is handicapped by the effects of altitude, high rainfall, and uncertain harvests. In such cases barley in particular is a risky venture, and it is felt that a " double-barrelled " crop is much more reliable, whatever the character of the season. There are also districts in Devonshire where barley does not succeed owing to the lack of lime in the soil, and it is safer, therefore, to sow a mixture of oats and barley. It is doubtful whether a heavier yield is obtained under good arable conditions, but in circumstances such as those outlined it is probable that, over a period of years, dredge corn does crop better than either oats or barley alone. That the crop stands better in bad weather is also an important consideration.

As a possible disadvantage, there is the difficulty in selling mixed corn should the turn of the market render it profitable to dispose of home-grown cereals and purchase imported feeding stuffs.

Rotation and Manuring—With regard to its position in the rotation, dredge corn usually takes the place of the cereal crop. It is often taken after roots or temporary pasture, while it may sometimes be grown as a second corn crop and seeds sown with it. In the latter circumstances it is customary to apply a fairly heavy phosphatic dressing for the benefit of the seeds which follow. When dredge corn succeeds a root crop no artificials are necessary, because the root crop is usually eaten off. On the other hand, if the roots are carted off, a light dressing of superphosphate and potash salts is applied at the time of seeding, and, if necessary, a top dressing of 1 cwt. per acre of nitrate of soda, as soon as the crop has established itself. No manure is usually applied if dredge corn is taken after a ley. As a general rule no special manuring is required for dredge corn, other than that used for an ordinary cereal crop.

Mixtures—The common mixture used in Devonshire is oats and barley; although wheat is sometimes included, it can be treated as negligible. The proportion of oats and barley varies considerably in different parts of the county, according to the nature of the soil, aspect, and the use to which the crop is to be put, but half oats and half barley is generally favoured. Two-thirds oats and one-third barley, and three-quarters oats and one-quarter barley, are also fairly common mixtures.

It is important that the varieties used should be such as ripen together as nearly as possible.

Seeding—The normal seed rate is 4 bushels per acre, but a heavier seeding is necessary on strong land. The seed is sown at the end of

DREDGE CORN AND MASHLUM (*Continued*)—

March, or in the first or second week in April, according to the season and locality.

With regard to yield, the amount of grain produced is usually in the neighbourhood of 20 cwts. per acre for a fairly good crop.

For feeding, the mixture is either crushed or rolled, and fed to fattening animals. In the case of cows a rich cake, such as decorticated ground-nut cake, is added, the dredge corn being used to make up the starch or carbohydrate portion of the ration.

Mashlum—In recent years it has become increasingly popular in Devonshire to introduce either peas or beans, as is done with the mashlum crop in the north, and where a legume is included the protein content of the food is raised, with a consequent saving in the cake bill. Many parts of the west country are unsuitable for growing peas or beans as pure crops, and the practice of growing mixed crops has therefore much to commend it. One drawback is the difficulty sometimes experienced in getting the ingredients to ripen at the same time.

For spring sowing, about a peck of peas is included in the ordinary dredge mixture, while in one or two districts autumn-sown mixtures of winter oats and beans are sown. Typical mixtures are as follows: (1) 2 bushels oats, 2 bushels barley, 1 peck peas or beans; (2) 3 bushels oats, 1 bushel barley, 1 peck peas or beans.

In considering the time of sowing, it is necessary to remember that beans require a longer period of growth than oats. This difficulty is surmounted by sowing the beans a few weeks earlier than the oats, and by using a late-ripening variety of oats.

C. D. R.

DRIED BLOOD—See Fertilizers.

DROUGHT RESISTANCE (in plants)—See Winter Hardiness and Drought Resistance.

DUCKS—See Poultry.

DYNAMOMETERS—Strictly speaking, the term connotes an instrument for measuring force, but in practice it is always employed for an instrument fitted for the measurement of work by recording in some way or other the two factors, force × distance, by whose product it is measured. The farmer is interested in two types of these instruments: (*a*) Those which may be used for testing the brake horse-power of an engine fly-wheel or motor pulley; and (*b*) those which may be used with ploughing or cultivating machinery to determine the work demand for ploughing or cultivation. Dynamometers of the first class are divisible into two types: *absorption dynamometers*, in which the energy is wasted in friction; and *transmission dynamometers*, in which the energy is employed in the usual way, the dynamometer itself absorbing very little.

The simplest type of absorption dynamometer is the rope brake type illustrated diagrammatically in Fig. 6. A rope is wound round the fly wheel of, *e.g.*, a traction engine, and while one end passes upward to a suitable spring balance suspended from a beam, the other hangs downward and supports some weights. In this state, apart from

DYNAMOMETERS (*Continued*)—

friction of the wheel bearings, etc., the spring balance B will read the weight W. If, now, the fly wheel is rotated in the direction of the arrow, the friction of the rope on the circumference will operate in such a way as to raise W slightly and allow the pointer of B to retreat on the scale. Thus, since W is opposing and B helping the rotation, the effective retarding force on the circumference will be W − B, and in one revolution the work absorbed will be $\pi D(W-B)$, where D is the diameter of the wheel and the diameter of the rope is negligible in comparison with this. Hence, if the wheel rotates n times per minute, the work absorbed per minute will be $\pi n D(W-B)$, whence, if W and B are measured in pounds and D in feet, we have

$$\text{Brake horse power} = \frac{\pi n D(W-B)}{33{,}000}$$

(since 1 h.p. = 33,000 ft. lbs./min.).

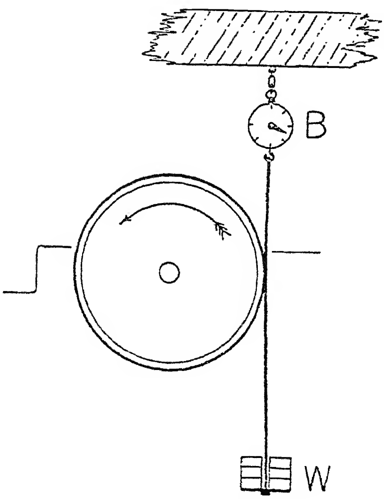


FIG. 6.—ROPE BRAKE DYNAMOMETER.

When the instrument is in use the rope is normally held in place on the circumference of the fly wheel by wooden blocks, and a lubricant is used. Even then the reading of the spring balance has a tendency to unsteadiness. This has been to a large extent overcome in the Appold compensated brake dynamometer, which is the same in principle as the foregoing, but for the part of the rope running round the fly wheel a band is substituted, the ends of which are fixed to a link fixed askew to the circumference of the wheel, so that a straightening of the link increases the effective diameter of the band, thus loosening it on the fly wheel. This link is rigidly attached to a lever, which is attached to a pin on the engine frame in such a way that any rise of the weight loosens the band and *vice versa*.

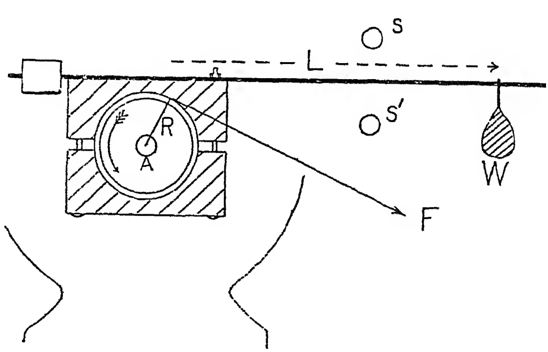


FIG. 7.—PRONY BRAKE DYNAMOMETER.

Another form of absorption dynamometer is the Prony brake, which

DYNAMOMETERS (*Continued*)—

is suited for use with pulleys of comparatively small diameter as on electric motors. In this type, illustrated in Fig. 7, two wood or fibre blocks made to fit the pulley are bolted to its circumference and to a long lever, the weight of which is balanced by a counterpoise. The frictional torque on the dynamometer is balanced by a contrary torque produced by a weight hung on the lever arm. Two stops (s, s') prevent any too great movement of the end of the lever. In this type the moment of frictional resistance about the axle A is equal to the frictional resistance × radius of pulley = FR = WL (see Fig. 7), whence $F = \frac{WL}{R}$. Now F corresponds precisely with the quantity (W − B) in the previous case, thus:

$$\text{Brake horse power} = \frac{\pi n DF}{33{,}000} = \frac{2\pi n WL}{33{,}000}.$$

The most usual type of transmission dynamometer is the Thorneycroft, in which the driving belt is carried round two pulleys placed at the ends of the cross piece of a T-shaped piece of iron. Passing from the driver the belt passes round one of the pulleys mentioned, then round the follower which is placed between the driver and the dynamometer, and finally round the second pulley of the dynamometer, and so back to the driver. Thus one dynamometer pulley is on the tight side and one on the slack side of the belt. The T piece is pivoted at the point where cross and upright meet, but with the cross vertical and the upright horizontal, the pulley on the tight side of the belt being on top. The difference in tension on tight and slack side exercises a torque about the pivot which is balanced by a weight, W (lbs.), placed at the distance L (ft.) along the horizontal portion—thus the work done per revolution if the diameter of the driver is D ft.

$= \pi D(T_1 - T_2)$, where T_1 and T_2 are the tensions in the belt

$= \frac{\pi DWL}{X}$, by equating moments, where X (ft.) is the length of the cross piece,

$$\text{whence brake horse power} = \frac{\pi n DWL}{33{,}000X}.$$

In recent years dynamometers have been used to investigate more closely the requirements of power for cultivating, and especially for ploughing. They are by no means complicated as far as the mechanism is concerned. Often a helical spring is mounted in an iron cradle so as to suffer compression when a tension is applied to the ends of the apparatus. A simple arrangement of the kind is illustrated in Fig. 8. This apparatus is then mounted between the whipple trees and the hake chain, and the degree of compression of the spring becomes a measure of the draw bar pull. This is communicated by means of a Bowden wire to a stylus working across a paper chart, which runs under it from one roller on to another. The rate of rotation of the drums, and consequently the rate at which the paper runs under the stylus, is controlled through a wheel train by the rate of rotation of a wheel

DYNAMOMETERS (*Continued*)—

bolted to the plough and running in the furrow. In this way the area included between the curve traced out by the stylus and the datum line of zero draw-bar pull becomes a measure of the *work* done in ploughing the furrow. This wheel must be kept free from caked earth. Using an instrument of this type, W. M. Davies (*J. Agric. Sci.*, xiv., 369-406, 1924) found that the draught varied directly as the depth and width of furrow slice, that there appeared to be an optimum moisture content above and below which the draw-bar pull was greater under like conditions for the same soil. He found the double plough to be more efficient *cæteris paribus* than the single.

In the subsequent investigations of B. A. Keen and W. B. Haines at Rothamsted in the following year, published in three papers (*J. Agric. Sci.*, xv., 375 *et seq.*, 1925), a modification was introduced in that the pressure was initially communicated to an oil pressure gauge which operated in its turn on the spring. The chart of this instrument showed time, distance, draw-bar pull, and depth of ploughing automatically, and it was also provided with special timing mechanism for indicating different points of interest in the field. These workers

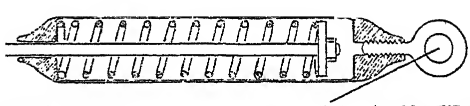


FIG. 8.—COMPRESSION DYNAMOMETER FOR USE BETWEEN WHIPPLETREES AND HAKE CHAINS.

opined that there was a fault in the usual force-distance computation for the purpose in hand, since if we imagine the plough brought to rest by an obstacle, then if the source of energy were a falling weight the draw-bar pull would be maintained without loss, whereas, when a tractor is used, this is clearly not the case. Again, when the ploughing was done up and down hill, the draw-bar pull was not greatly changed, but the power output was different for the same distance owing to the slower speed. They employ a "power factor" = draw-bar pull × time in seconds to plough 1 ft. length. In other words, they realize that what is required in practice is not a measure of the actual work done, but of the power expended in doing it, *including waste.*

They confirmed the observations of Davies that the draught varies directly as the depth of ploughing. Slopes up to 1 in 40 they found to be without appreciable effect on the draw-bar pull, and that this only varied slightly with speed, whence it follows that it is more economical to plough rapidly. Variations of draw-bar pull over the surface of a field were found to show correlation with clay content and with the growth of crop in its early stages. One surprising result on the Broadbalk field at Rothamsted was that the parts from which the drain efflux after heavy rain was greatest were the heaviest for plough-

DYNAMOMETERS (*Continued*)—
ing and *vice versa*. This may be connected with the optimum moisture content suggested by Davies.

In a subsequent paper (*J. Agric. Sci.*, xviii., 724, 1928) the same authors describe an improved form of their instrument, in which the oil pressure is transmitted directly to a Bourdon gauge. The variations in length of the arc of this are magnified by a precise lever mechanism, and recorded as a groove in a celluloid strip by means of a blunt stylus. The record is permanent and easily magnified for integration, and the whole apparatus only weighs something in the neighbourhood of 100 lbs.

T. D.

EARTH NUT—For composition and feeding value see Feeding Stuffs; for manurial value see same, under Feeding Stuffs.

EDUCATION, AGRICULTURAL—See various articles under Agriculture; also Agricultural Research and Education in England.

EGG—See Poultry. For composition, etc., of, see Poultry Nutrition.

ELEMENTS, CHEMICAL—The term *element* has varied in meaning from time to time. In the earliest ages there were thought to be but four—Earth, Air, Fire, and Water—and the conception, even then, was one rather of a compound nature; the "quintessence" was the same in each case; they differed only in the "eidos" with which this was endowed. This idea held sway throughout the Middle Ages, backed by the authority of Aristotle, and was doubtless sustained in its later life by the respect accorded to the Thomist philosophy, which was purely Aristotelian in character.

However this may be, it was not seriously questioned until the seventeenth century, when Robert Boyle and his followers declared that we should regard as elementary those substances which the means at our command do not permit us to break up into anything simpler; and, in spite of the tremendous strides made by science in the last 300 years, it is only in the present century that this definition is beginning to be a little unsatisfactory.

The nineteenth century, it is true, brought to light allotropic forms of some of the elements, and while it was simple to regard both white and red phosphorus as one element, both having the empirical formula P_4, it was less easy to make a satisfactory decision as to oxygen (O_2) and ozone (O_3), since the latter acts in many ways as a very active and unstable compound.

The present century has brought the two further complications of the discovery of the existence of isotopes by Aston and artificial splitting of some well-known "elements" by Rutherford by radioactive means, and it becomes necessary, if a really satisfactory definition is to be given, that the ideas of subatomic chemistry should be drawn upon. From this viewpoint one may define an element as a substance whose atom consists of nuclei, each having the same number of circulating electrons, both these and the atoms being in one

ELEMENTS, CHEMICAL (*Continued*)—

of the simplest states of association in which they are capable of existing under normal conditions. This the writer considers would get over the difficulty of the allotropic form of oxygen by definitely excluding ozone, while isotopes would be included, as also such substances as ortho- and para-helium, which differ only in the disposal of the magnetic moments of their electronic orbits.

The word *atom* is used in the definition, but this will offer little difficulty, since there seems as yet no reason to go behind the nineteenth-century definition of this as "the smallest portion of any substance which can be made to enter into or to be expelled from a chemical compound," except, perhaps, to add the words "by chemical means."

Subatomic chemistry, however, has in recent years enabled us to get a much clearer picture of these ultimate "particles" of matter. They each consist of an equal number of positively and negatively charged centres of electrical force; the term *particle* is avoided as giving a wrong idea. The positive and some of the negative charges are aggregated at the centre of the atom to form a nucleus, and the remaining negative charges (electrons) apparently circulate around the nucleus in orbits similar to and obeying the same laws as those of the planets round the sun, with changes suited to the very different conditions. One says "apparently" circulate because the idea of the position of the electron in its orbit at any moment is meaningless unless the orbit is very large. To quote Eddington's words: "Something unknown is doing we don't know what."

The ordinary physical and chemical properties of a substance depend on the constitution of the electron cluster round the nucleus, *e.g.*, the orbits fall into natural groups, and if only *one* electron is in the outer group of orbits while all inner groups are in a sense full up, the result is an alkali metal. Small variations in the nucleus, on the other hand, result in the production of *isotopes*—that is, specimens of the substance which are identical with it in all chemical and physical respects, except that its atomic weight is slightly different. Nearly half the elements have been found to have more than one isotope. One isotope differs from another of the same substance in having a greater or less positive charge in the nucleus, and this augments or reduces the atomic weight by unity, and in this we find the ultimate foundation on which Prout's hypothesis, that the atomic weight of all the elements should really be whole numbers, was built. Of course, Prout knew nothing of isotopes, but he observed that the atomic weights of most elements approximated to integers, and thought that if only experimental methods could be perfected, they would be found to be so, actually the atomic weight of a pure specimen of an isotope would be a whole number. Here we have an additional justification for adopting $O = 16$ as our standard for atomic weights, as oxygen has no isotope.* Of course, the change to this standard instead of

* Giauque and Johnston (*J. Amer. Chem. Soc.*, December, 1929, pp. 3528-34) claim to have discovered two such of atomic weights 17 and 18. If this should be confirmed the above remark is of course pointless.

ELEMENTS CHEMICAL (*Continued*)—

H = 1 was made years ago from the point of view of accuracy and convenience, since atomic weights are almost always determined by comparison with oxygen, not hydrogen.

It is clear that we shall require a new and modified definition of atomic weight to allow for the new facts which have come to light, and the following is given by Professor T. W. Richards in the fourteenth edition of the *Encyclopædia Britannica*: "Primarily atomic weights are appropriate simple multiples decided by theory of the relative combining proportions or relative gas densities of elementary substances calculated on a consistent basis. They represent the relative average weights of the atoms of given specimens of elementary substances referred to a common standard."

This suggests one very pertinent question—namely, if the atomic weights are merely *averages* of the atomic weights of isotopes in mixtures, why are these averages in general quite constant, *e.g.*, silver is found to have the atomic weight 107·88 wherever it comes from? The answer is that the deposits of the elements, or the mixing of the isotopes, took place when the earth's crust solidified; until that time all parts had been subject to fairly similar conditions, and after it the differences have not been such as to affect the course of any nuclear changes which take place in general spontaneously and without reference to external conditions. The atomic weight of radio-lead, an isotope of ordinary lead, varies, since these conditions do not apply.

In 1869 Mendeleef made the remarkable discovery that if the elements then known were arranged in series of eight in the order of their atomic weights, the elements which fell into the different series resembled one another in general chemical and physical properties, and not only that, but that these properties varied regularly in a single series with increase in atomic weight, *e.g.*, Fluorine, Chlorine, Bromine, and Iodine form one such series; Lithium, Sodium, Potassium, Rubidium, and Cæsium another. By this table Mendeleef was able to prognosticate the discovery of new elements and to state approximately the properties they would have. The elements Gallium, Scandium, and Germanium were later discovered, and their properties approximated closely to the values Mendeleef had given.

As time went on, however, it became clear that there was something not quite right about the table, since some elements had to be put in their wrong order to fit in with the general scheme, notably Potassium and Argon, Iodine and Tellurium; and every subsequent more accurate determination of the atomic weights of these elements only served to emphasize this inversion. These disparities vanish entirely if, instead of arranging the elements in order of their atomic weights, we do so in order of their atomic numbers. The atomic number represents the magnitude of the nuclear charge, or what amounts to the same thing is equal to the number of circulating electrons in the atom; moreover, we must not *blindly* take every eighth element, but must set out the table in accordance with types of electron orbits. It would take us too far to discuss this point in

ELEMENTS, CHEMICAL (*Continued*)—

greater detail. The following table gives a list of the elements known, classified by orbit types, and the relation of these to the periodic classification will be seen. No element is found on earth with atomic number exceeding 92 (Uranium), but Jeans considers it probable that others up to at least atomic number 95 may be present on some of the stars. It will be noticed that suitable tenants are still to seek for the spaces opposite atomic numbers 85 and 87. The former ought to be occupied by a halogen, the latter by an alkali metal. There can be no reasonable doubt that these will eventually be discovered; indeed, the spaces in the scheme have been reduced by one as lately as 1926, when Illinium was detected by spectrum analysis.

Valency, on this new theory of the atom which ushered in the present century, acquires a new significance as the number of electrons effective in chemical combination. These appear not to be able to exceed eight, and herein lies the justification of Mendeleef's Periodic Law. While the noble gases Helium, Argon, etc., exhibit valency = 0, Osmium and Ruthenium form compounds OsF_8 and RuO_4, in which the maximum valency is shown.

Reference should perhaps be made to the discovery in the last two years that both Helium and Hydrogen molecules exist in two forms, according as the magnetic moments of the electronic orbits of the atoms are of the same or opposite sign. It would, on the other hand, not be surprising if differences due to this cause ceased to be detectable when elements of higher atomic number are investigated, owing to the very complicated systems of electron orbits which these carry with them.

The following *alphabetical* list of elements, with their atomic numbers, will enable any element to be located in the table from its atomic number:

Actinium, 89	Fluorine, 9	Neodymium, 60	Silver, 47
Aluminium, 13	Gadolinium, 64	Neon, 10	Sodium, 11
Antimony, 51	Gallium, 31	Nickel, 28	Strontium, 38
Argon, 18	Germanium, 32	Nitrogen, 7	Sulphur, 16
Arsenic, 33	Gold, 79	Osmium, 76	Tantalum, 73
Barium, 56	Hafnium, 72	Oxygen, 8	Tellurium, 52
Beryllium, 4	Helium, 2	Palladium, 46	Terbium, 65
Bismuth, 83	Holmium, 67	Phosphorus, 15	Thallium, 81
Boron, 5	Hydrogen, 1	Platinum, 78	Thorium, 90
Bromine, 35	Indium, 49	Polonium, 84	Thullium, 69
Cadmium, 48	Iodine, 53	Potassium, 19	Tin, 50
Calcium, 20	Iridium, 77	Praseodymium, 59	Titanium, 22
Carbon, 6	Iron, 26	Protoactinium, 91	Tungsten, 74
Cæsium, 55	Krypton, 36	Radium, 88	Uranium, 92
Cerium, 58	Lanthanum, 57	Radon, 86	Vanadium, 23
Chlorine, 17	Lead, 82	Rhenium, 75	Xenon, 54
Chromium, 24	Lithium, 3	Rhodium, 45	Ytterbium, 70
Cobalt, 27	Lutecium, 71	Rubidium, 37	Yttrium, 39
Columbium, 41	Magnesium, 12	Ruthenium, 44	Zinc, 30
Copper, 29	Manganese, 25	Samarium, 62	Zirconium, 40
Dysprosium, 66	Masurium, 43	Scandium, 21	
Erbium, 68	Mercury, 80	Selenium, 34	
Europium, 63	Molybdenum, 42	Silicon, 14	

ELEMENTS, CHEMICAL (*Continued*)—

TABLE OF CHEMICAL ELEMENTS.

Atomic Number.	*Name of Element.*	*Symbol.*	*Atomic Weight.**	*Sub-Atomic Constitution.*
1	Hydrogen	H	1·0077	K ring orbits only, all circular.
2	Helium	He	4·00	
3	Lithium	Li	6·939	L ring orbits, in addition to K
4	Beryllium[12]	Be	9·02	ring as above.
5	Boron	B	10·82	L ring orbits are of two types,
6	Carbon	C	12·00	circular and elliptic.
7	Nitrogen	N	14·008	
8	Oxygen	O	**16·000**[1]	
9	Fluorine	F	19·00	[Li has only one electron in the
10	Neon	Ne	20·2	L ring.]
11	Sodium	Na	22·997	M ring orbits, in addition to K
12	Magnesium	Mg	24·32	and L rings as above.
13	Aluminium	Al	26·96	M ring orbits are of three types,
14	Silicon	Si	28·06	one circular and two elliptic of
15	Phosphorus	P	31·024	different eccentricities.
16	Sulphur	S	32·065	
17	Chlorine	Cl	35·458	[Na has only one electron in the
18	Argon	A	39·91	M ring.]
19	Potassium	K	39·095	N ring orbits, in addition to K.
20	Calcium	Ca	40·07	L, and M rings as above.
21	Scandium	Sc	45·10	N ring orbits are of four types,
22	Titanium	Ti	47·9	one circular and three elliptic of
23	Vanadium	V	50·96	different eccentricities.
24	Chromium	Cr	52·01	
25	Manganese	Mn	54·93	
26	Iron	Fe	55·84	
27	Cobalt	Co	58·97	
28	Nickel	Ni	58·69	
29	Copper	Cu	63·57	
30	Zinc	Zn	65·38	
31	Gallium	Ga	69·72	
32	Germanium	Ge	72·38	
33	Arsenic	As	74·96	
34	Selenium	Se	79·2	
35	Bromine	Br	79·916	[K and Cu have each only one
36	Krypton	Kr	82·9	electron in the N ring.]
37	Rubidium	Rb	85·44	O ring orbits in addition to K, L,
38	Strontium	Sr	87·62	M, and N rings as above.
39	Yttrium	Yt[8]	89·0	O ring orbits are of five types,
40	Zirconium	Zr	91·0	one circular and four elliptic of
41	Columbium[13]	Cb	93·1	different eccentricities.
42	Molybdenum	Mo	96·0	
43	Masurium	Ma	—	
44	Ruthenium	Ru	101·7	
45	Rhodium	Rh	102·91	
46	Palladium	Pd	106·7	
47	Silver	Ag	107·880	
48	Cadmium	Cd	112·41	
49	Indium	In	114·8	
50	Tin	Sn	118·7	
51	Antimony	Sb	121·77	
52	Tellurium	Te	127·5	
53	Iodine	I[2]	126·932	[Rb and Ag have each only one
54	Xenon	Xe	130·2	electron in the O ring.]

* Values from International Critical Tables.

ELEMENTS, CHEMICAL (*Continued*)—

TABLE OF CHEMICAL ELEMENTS—*Continued.*

Atomic Number.	*Name of Element.*	*Symbol.*	*Atomic Weight.**	*Sub-Atomic Constitution.*
55	Cæsium	Cs	132·81	P ring orbits, in addition to K, L, M, N, and O rings as above.
56	Barium	Ba	137·37	
57	Lanthanum	La	138·91	P ring orbits are of six types, one circular and five elliptic of different eccentricities.
58	Cerium	Ce	140·25	
59	Praseodymium	Pr	140·92	
60	Neodymium	Nd	144·27	
61	Illinium	Il	?	
62	Samarium	Sa[14]	150·43	
63	Europium	Eu	152·0	
64	Gadolinium	Gd	157·26	*Rare (Gadolinite) earth metals.* (57–71)
65	Terbium	Tb	159·2	
66	Dysprosium	Ds[4]	162·52	
67	Holmium	Ho	163·4	
68	Erbium	Er	167·7	
69	Thullium	Tm[5]	169·4	
70	Ytterbium	Yb	173·6	
71	Lutecium[9]	Lu	175·0	
72	Hafnium[11]	Hf	(178·6)	
73	Tantalum	Ta	181·5	
74	Tungsten	W	184·0	
75	Rhenium	Re	—	
76	Osmium	Os	190·8	
77	Iridium	Ir	193·1	
78	Platinum	Pt	195·23	
79	Gold	Au	197·2	
80	Mercury	Hg	200·61	
81	Thallium	Tl	204·4	
82	Lead	Pb	207·2	
83	Bismuth	Bi	209·00	
84	Polonium	Po	(210)	
85[6]				[Cs and Au have each only one electron in the P ring.]
86	Radon[10]	Rn	222	
87[7]				Q ring orbits, in addition to K, L, M, N, O, and P rings as above.
88	Radium	Ra	225·95	
89	Actinium	Ac		
90	Thorium	Th	232·15	Q ring orbits are theoretically of seven types, one circular and six elliptic, but in the normal statile state only those of elliptic form and great eccentricity are occupied in the case of the elements shown.
91	Protoactinium	Pa		
92	Uranium	U	238·17	[Ra has two electrons in the Q ring, Ba two electrons in P ring, Sr two in the O ring, etc.]

* Values from International Critical Tables.

NOTES TO TABLE OF CHEMICAL ELEMENTS.

[1] The standard to which all other atomic weights are referred.

[2] Or J in many countries of Europe.

[4] Dy sometimes used but liable to confusion with a mixture of praserdymium and neodynium once called Didynium, and thought to be an element.

ELEMENTS, CHEMICAL (*Continued*)—

NOTES TO TABLE OF CHEMICAL ELEMENTS—*Continued.*

[5] Or Tu.
[6] A missing halogen.
[7] A missing alkali metal.
[8] Or Y.
[9] Also called Cassiopeium, symbol Cp.
[10] Also called Niton, symbol Nt, and Radium Emanation, symbol Em.
[11] Also called Celtium, symbol Ct.
[12] Also called Glucinium, symbol Gl.
[13] Also called Niobium, symbol Nb.
[14] Or Sm.

The notes in square brackets in the last column of the table show the connection with the periodic classification, the difference between the odd and even series elements—*e.g.*, K, Cu; Rb, Ag; Cs, Au; depends on differences in the orbits occupied by electrons in the rings inside the outermost. The Gadolinili earth metals differ from one another chiefly in the constitution of their N rings.

T. D.

ENDIVE—See Market Gardening.

ENERGY—When a point moves against a resisting force of whatever nature, *work* is done, and the amount of work which is done is measured by the product—magnitude of resisting force × the distance through which the point moves against it. This is the physical definition of work, and energy is simply defined as ability to perform work, and is measured by the amount of work that there is ability to perform. In considering energy from this point of view, it is quite immaterial whether practical means of realising this energy in the form of mechanical work exist or no, *e.g.*, solid helium contains a small amount of energy by virtue of the motion of its molecules constituting the small amount of heat left in it at that very low temperature. No practical means of utilizing this are conceivable, but if a perfect reversible heat engine working between the temperature of solid helium and the absolute zero could be made, this energy could be realised as mechanical work. This seems very theoretical, but all forms of energy whatsoever are reducible to terms of mechanical work, and can be measured as above. For practical purposes it is often more convenient to measure energy in terms of heat, since under ordinary conditions this is the only form into which all the others can be quantitatively converted, and it has been established that one grm.-calorie of heat is always exactly equivalent to $4{\cdot}18 \times 10^7$ ergs of mechanical work. The further discussion of these phenomena forms the subject matter of the science of thermodynamics. The forms of energy met with in nature are heat, ability to do mechanical work either by virtue of position (potential energy) or of motion (kinetic energy), including sound, also radiant energy, which includes light, both visible and ultraviolet, cathode rays, X rays, etc., radiant heat, and the electric waves employed in wireless telegraphy; chemical and sub-atomic potential energy, and the energy of electrical potential differences, and the farmer is concerned with most of these in one way or another. The overshot water wheel makes use of the potential energy due to the elevated position of the ingoing water stream with reference to the outflow; the water turbine or pelton wheel employs the kinetic

ENERGY (*Continued*)—

energy of a rapidly moving water stream, as also does the hydraulic ram.

The work of the last few years in theoretical physics shows that we must envisage the possibility that matter itself is but a form of energy and that it is quantitatively convertible into radiant energy and *vice versa*. If this change is going on, as seems probable, it is a process of which we have as yet no control, unlike the others mentioned, which may be diverted to the service of man.

ENSILAGE—Introduction—Ensilage is the practice of preserving fodder crops in succulent condition for use as cattle food at a later date. It has been slow to gain a footing in British farming practice for two reasons: first, because, when it was brought originally to the attention of farmers in the early eighties of the last century, very little attention was given to the careful scientific study of the process, with the result that many mistakes were made and a great deal of inferior silage was produced; secondly, because, previous to 1914, the cost of farm labour was very low, so that the economy of labour resulting from the practice did not influence farmers in its favour. At the present time, with high labour costs combined with the rapid development of farm machinery, there are strong reasons for the extension of the practice. Ensilage not only compares favourably with root-growing in labour costs, but it lends itself to large-scale farming on factory lines, and fits in extraordinarily well with most systems of farming. The crop, as commonly grown, facilitates the destruction of weeds, partly because these are smothered under the dense foliage and subsequently cut and ensiled before their seeds are shed, and partly because the crop is cleared from the field in early summer, and the land consequently can be broken up in hot weather by steam or tractor and the perennial weeds quickly destroyed.

Materials Suitable for Silage—Nearly all the crops utilized as green forage, except those of the cabbage tribe, are also suitable for silage. Grass, when conditions are not favourable to hay-making, as, for example, sewage grass, water-meadow grass, late autumn grass, can be made into excellent silage; mixed grasses and clovers on arable land are very suitable, especially heavy crops in rainy weather, and second and third crops; even partially spoilt hay, provided it has not been turned and is still succulent, can be utilized in this manner. Hay that has once dried out, however, is wholly unsuitable as silage.

Crops composed wholly of the usual leguminous crop plants generally result in high-smelling silage, which is not so good as that derived from a mixed crop. The best silage crops in this country are made from mixed crops of oats and tares or oats and peas on light land, or beans, oats, and tares on heavy land; where it can be grown well, the bean crop is specially suitable, because not only does it result in excellent silage, but having stiff stems, these help to hold up the weaker trailing-stemmed tares. These weak stems of the tares are unfortunate, for otherwise the tare crop is very suitable. If too heavy a seeding is given, and the resulting crop is laid, much of it is wasted, while the quality of the silage suffers also. Generally, the quantity of tares in

ENSILAGE (*Continued*)—

the seed mixture should not exceed two bushels per acre on light, poor land, and 5 pecks on rich or heavy land. All oats are not equally suitable, and the choice for this purpose should lie with a variety with a fairly stiff and yet not too coarse a straw, so that it may help to support the crop.

Again, for an autumn-sown crop in particular, it is important that the variety chosen should shoot its stem early, and so keep ahead of the tares, for if the tendrils of these once overtop the oats, the latter are pulled down, and thus fail in the very purpose for which they were included in the mixture.

Grey Winter oats, in addition to possessing the requisite degree of winter hardiness, are characterized by an ability to develop rapidly in the spring. Rates of seeding for autumn sowing on light land are 6 to 8 pecks of tares with 8 to 10 pecks of oats, and on heavy land 3 to 5 pecks of tares with 8 pecks of winter beans and 4 to 6 pecks of oats.

The above-mentioned crops are those most commonly grown in this country for silage, but in America and other parts of the world, maize, sorghum, and sunflower are much more frequently grown. Sorghum is not suitable in the British Isles, nor are most of the American maizes, but there are early-maturing varieties which can be grown to great advantage. A French variety named "Jaune Gros du Domaine" is perhaps the best, and the American varieties Salzer's North Dakota and Longfellow are suitable on very early soils. Sunflowers are usually grown abroad if the climate is too cold for maize, because, like that plant, they can be grown, cut, and ensiled so easily, in addition to producing a great bulk of fodder from a small and cheap seeding; the sunflower is indeed worth more careful study in this connection in this country.

Systems of Ensiling—There are three main systems for making silage, either in a specially constructed building called a silo to be filled each year, or, for occasional use, the silage clamp or the silage stack can be used.

Constructed Silos—A silo is usually made of wood or of concrete, and takes the form of a tall cylindrical structure 30 or more feet in height and varying between 12 and 20 ft. in diameter. Silage can be made most satisfactorily in these, and with little accompanying waste, but they generally entail a large capital outlay. On the other hand, clamps and stacks usually entail much waste but involve little outlay of capital.

Crops are cut for silage when their degree of maturity has reached a stage rather more advanced than that requisite with hay-making as the objective; thus, oats and tares should be cut when the oats are in full milk and when the tare pods are fully grown in length with the seeds half-grown in the pod. If the crop is very succulent, it is desirable to allow the crop to wither for six to twenty-four hours in the field, but if it is over-mature, it should be ensiled as quickly as possible. Very succulent silage, or silage wet with rain, tends to lose much juice

ENSILAGE (*Continued*)—

by drainage; on the other hand, very dry silage packs loosely, heats too much, and does not possess as high a feeding value.

Whilst it is preferable to make silage in fine weather, this is not essential, and, indeed, the ability to continue the operation under almost any weather conditions constitutes one of its chief advantages. Crops which have become badly laid and rotten at the base should not be ensiled, however, until the rain water has dried, for they are liable to give rise to "sour" silage.

The green crop is generally chaffed and blown into the tower silo with the help of a silage cutter and blower. In the silo the material should be spread equally over the surface, keeping the centre slightly higher than the sides, and the whole firmly trampled. To secure the full benefit of the silo capacity, it is especially important to trample very tightly, as the top is reached, and if the filling process can be extended for an additional day or two to give time for the silage to settle, the capacity can be still more efficiently used. Finally, the top layers of the silo should be composed of moist succulent material, otherwise the crop should be moistened whilst filling to ensure tight packing, thus reducing the wastage by moulding of the exposed surface to a minimum. It is not generally considered advisable to cover the silage in a tower with earth or other material to prevent this waste, since the cost of labour involved is greater than the value of the silage saved.

Silage Clamps—Silage clamps can be improvised at very short notice. The site should be carefully chosen so that this does not become waterlogged in winter, and it should be convenient for carting in and out. The floor should be excavated to a depth of from 1 to 3 ft. with a rectangular shape and the earth thrown to the sides. The width should be between 12 and 16 ft.; the length according to the quantity of crop to be handled. In filling the clamp it is not usual to chaff the crop, but the clamp is made just as a drawn-over dung-heap, each successive load being drawn over the silo by the horse and then unloaded. Silage made in clamps is somewhat liable to be "sour" at the bottom because access of air, which is essential to the heating process, is limited both by the earthen walls of the clamp and by the very close compaction of the clamp by the weight of the loaded carts.

The production of "sour" silage may be prevented if steps are taken to encourage heating in the lower layers. This may be done either by filling the bottom of the clamp with partially withered material so that it does not pack so tightly, or, when a layer 2 ft. deep has been formed, a halt may be made to allow the fermentation process to commence before the rest of the clamp is made. If this is done, the heat will spread through the rest of the clamp, and the resulting silage will be "sweet" and palatable. The time required to start the heating may be two or three days, but once heating has commenced, filling may proceed rapidly up to a height to which the horses can draw. The clamp will continue to heat, and the whole will settle down so that building can be resumed several times. When finally topped

ENSILAGE (*Continued*)—

up, the clamp should be quickly covered with earth. It is preferable to cover the top of the clamp first and then throw earth against the sides, for if the sides are covered first, as in a mangold clamp, these tend to support the earth on the top like a roof and so reduce the pressure on the material inside.

Silage Stacks—Silage stacks can be used to best advantage during a wet hay-time to save a partially spoilt crop, because in this case the tendency is to make "sweet" silage. Such stacks should be built on a very level floor, preferably in a sheltered situation. No stack bottom should be used, but the silage should be built directly on the earth floor. If otherwise, air gains access and the bottom layers become mouldy. Building is facilitated by an elevator or a horse-fork, since the silage crop is heavy to pitch. The stack must not be run up too quickly lest it should heat badly, settle irregularly, and topple over.

This is particularly liable to happen if the wind blows continuously from the same quarter; in this case the trouble may be minimized by hanging a sailcloth against the windward side of the stack, thereby preventing the wind from blowing through the stack. The top of the stack should be covered, if possible, with a good layer of succulent crop, which by its weight will assist in consolidating the whole; and in the event of the crop being dry it is advisable to add water to it from a hose-pipe as it ascends the elevator. Finally, the stack requires some means of pressing; formerly special presses were used, but they are expensive. Wibberley has suggested building a haystack on top, or alternately covering the top with a layer of soil 1 ft. deep, elevated in bags by means of a horse-fork. Another method consists of building a ridged roof, placing several poles lengthwise along the roof on the ridge and the eaves, then stretching wires over the ridge with bags of earth or other heavy weights fastened to each end.

There is no danger in feeding silage to stock immediately it is made, or it may be stored, without loss, for long periods, provided access of air is prevented; cases are on record of silage having been so kept for three or four years in perfect condition. In clamps or stacks silage tends to waste continuously owing to the access of air and rain; for this reason such silage should be consumed at an early date if it is convenient to do so.

A. A.

CHEMICAL CHANGES DURING ENSILAGE—The changes which modify the character of a green crop during its conversion into silage are brought about by the operation of three factors:

1. *The Respiration of the Plant Cells*—When the chaffed crop is filled into the silo, the cells of the plant material continue to respire. As a consequence of this activity, a portion of the carbohydrate of the crop is oxidized to carbon dioxide and water. This change is accompanied by the production of heat, and the temperature of the ensiled material rises accordingly. It is clear, therefore, that heating in the silo implies destruction of carbohydrate and the loss of nutrient matter. The magnitude of this loss, however, is frequently exaggerated. Woodman and Amos (*J. Agric. Sci.*, xvi., 539, 1926) have

ENSILAGE (*Continued*)—
demonstrated that if the amount of carbohydrate oxidized during the period of cell respiratory activity is equal to 2 per cent. of the dry matter of the crop, the heat generated is sufficient to raise the temperature of the mass of material from 20° to 50° C., *i.e.*, to a temperature at which the plant cells cease to respire, and high enough to ensure the production of "sweet" silage.

2. *The Activity of Plant Enzymes*—During ensilage, the protein of crop is acted on by proteolytic enzymes, pre-existent in the crop, with the result that it is, to a very significant extent, hydrolysed to its constituent amino acids. The extent of this enzymatic hydrolysis may be gauged from the data in Table I., in which a comparison is given of the composition of green oats, vetches and beans, and that of the silage which resulted from the ensilage of this crop in the tower silo. The figures are given on the basis of dry matter (Woodman and Amos, *J. Agric. Sci.*, xiv., 99, 1924).

TABLE I.—COMPOSITION OF GREEN OATS, VETCHES AND BEANS, AND OF OAT, VETCH AND BEAN SILAGE (DRY MATTER BASIS).

	Green Crop. Per Cent.	*Silage.* Per Cent.
Crude protein	9·69	9·86
Ether extract	4·09	5·24
Nitrogen-free extractives	51·22	47·88
Crude fibre	26·19	26·78
Ash ..	8·81	10·24
True protein	7·55	4·05
"Amides"	2·14	5·81

3. *The Activity of Bacteria*—The production of organic acids is perhaps the most characteristic feature of the changes occurring in the silo. The organic acids most commonly occurring in silage are acetic acid, propionic acid, butyric acid (usually referred to as the volatile acids), and lactic acid (usually termed the non-volatile acid). They arise partly as a consequence of incomplete oxidation of carbohydrate during the period of cell respiration in an insufficient supply of oxygen, and partly from the action of micro-organisms on the carbohydrate of the crop. With "sour" silage, lactic acid is present in smaller amount than the sum of the volatile acids, the latter being mainly composed of butyric acid (Amos and Woodman, *J. Agric. Sci.*, xv., 444, 1925). In unspoilt tower silage, however, lactic acid is present in excess, usually very appreciable, of the volatile acids, the latter consisting almost wholly of acetic acid. In properly made tower silage, butyric acid should be entirely absent. The following figures are typical for good maize silage, on the basis of the moist material: Acetic acid, 0·41 per cent.; propionic acid, 0·04 per cent.; lactic acid, 0·89 per cent.; butyric acid, 0·00 per cent.

4. Another interesting change during ensilage is that which concerns the chlorophyll of the green crop. As a consequence of the action of organic acids arising during preservation, the green pigment is transformed into a magnesium-free compound, known as phæophytin

ENSILAGE (*Continued*)—

(Woodman, *J. Agric. Sci.*, xiii., 240, 1923). Since the latter may exist in forms varying in colour from olive green to yellowish-brown and brownish-black, it follows that the colour of silage does not constitute a safe guide in regard to quality.

Types of Silage—Work at Cambridge on the ensilage under different conditions of green oats and vetches has led to the recognition of five distinct types of silage—namely, "sweet" silage, "acid brown" silage, "green fruity" silage, "sour" silage, and "musty" silage (Amos and Williams, *J. Agric. Sci.*, xii., 323, 1922).

"*Sweet*" *Silage*—This type of silage has a sweet, pleasant smell, similar to that of over-heated hay. It is usually comparatively dry and is readily eaten by livestock. The main factor in its production is that of temperature, "sweet" silage arising when the temperature of the ensiled crop rises beyond 50° C. Lactic acid is the characteristic acid of "sweet" silage, since fermentation is dominated by the lactic bacteria when the temperature rises above 50° C. The production of this type of silage may be assured by ensiling green crops under the following conditions:

1. By the ensilage of a comparatively dry crop, either one that is dry from being mature, or from being allowed to dry somewhat after cutting. Since cell respiration is an oxidative process, it follows that the extent to which the change occurs will depend largely on the supply of air remaining in the crop after filling into the silo. If the crop is comparatively dry, it does not pack so tightly, and consequently more air is retained. Under such conditions, a relatively high temperature may be attained in the silo. A similar result will be obtained if the process of filling the silo is carried out intermittently instead of continuously. The attainment of a high temperature is further facilitated under these conditions by the fact that the specific heat of a crop is lowered as its moisture content is reduced.
2. By making silage in stacks (Woodman and Hanley, *J. Agric. Sci.*, xvi., 24, 1926), since under these conditions air has much freer access to the crop than under the conditions of tower ensilage.
3. By bringing the temperature of the ensiled fodder to 50° C. by artificial means, as in the making of "electro-silage," in which process the crop is heated by the passage of an electric current.
4. By inoculating the green fodder with preparations containing cultures of lactic bacteria, with the object of encouraging the type of fermentation associated with the production of "sweet" silage.

"*Acid Brown*" *Silage*—This type of silage has a yellow-brown to brown colour, and an acidic though quite pleasant odour, largely due to the presence of acetic acid. It is the commonest type of silage produced in tower silos, and is readily eaten by stock. It results from the ensilage of reasonably mature crops, which have been allowed to wilt for some hours after cutting in order to ensure a dry matter content in the neighbourhood of 30 per cent. Many observations have shown that the maximum temperature attained in the production of "acid brown" silage varies between 30° and 40° C.

ENSILAGE (*Continued*)—

"*Green Fruity*" *Silage*—This type of silage has a green to olive-green colour, and a smell that is best described as "fruity," this being due to the occurrence of fermentative changes which lead to the production of small amounts of fragrant-smelling esters. "Green fruity" silage is distinctly superior to the "acid brown" type in respect of digestibility, nutritive value, and palatability, the feeding values, on the basis of dry matter, being roughly in the ratio of 7:5 (Wood and Woodman, *J. Agric. Sci.*, xi., 304, 1921; and Woodman, *J. Agric. Sci.*, xii., 144, 1922).

"Green fruity" silage is produced when an oat and vetch crop is ensiled in a medium stage of maturity, when the oats are in full milk and the vetch pods full-grown in length, with seeds barely half formed. The crop should be ensiled without wilting. The temperature of fermentation associated with the production of this type of silage is about 30° C.

"*Sour*" *Silage*—This type of silage has a dark brown to olive-brown colour, and an extremely unpleasant smell arising from the presence of butyric acid. It is usually produced when a very immature and succulent crop, such as immature green maize, is ensiled. The ensiling of such a crop, which settles down compactly and thereby leads to a more thorough exclusion of air, is usually associated with a low temperature rise. Under such conditions, the course of fermentation is uncertain, and "sour" silage, containing butyric acid and little or no lactic acid, usually results. Further, when the temperature of fermentation is low, certain undesirable micro-organisms may become active and bring about changes of a putrefactive character, giving rise to ammonia and allied substances of a useless and sometimes harmful character. These changes are brought about at the expense of the crude protein in the crop, and abundant evidence of such activity is obtained when "sour" clamp silage is submitted to analysis. In all types of unspoilt silage, however, such as the types already dealt with, the amount of ammonia is exceedingly small (Woodman, *J. Agric. Sci.*, xv., 343, 1925).

"*Musty*" *Silage*—Spoiling by mould activity only occurs when air is permitted free access to the chaffed crop. In such a case the mass may become distinctly alkaline instead of acid, and the material is thereby rendered unfit for consumption. In the tower silo, however, this type of silage is only found in the surface layer, and good acidic silage is encountered at a depth of a few inches. In the making of stack silage, on the other hand, considerable wastage may occur as a result of mould action, especially if the stack be carelessly finished off.

Feeding Value of Silage—It has been demonstrated that good tower silage is little, if at all, inferior in digestibility and nutritive value to the green crop from which it was made, or to hay made under good conditions from the same green crop. In an investigation carried out at Cambridge (Woodman, *J. Agric. Sci.*, xii., 144, 1922), determinations were made of the digestibility of green oats and vetches, and also of hay and silage made from the oat and vetch crop, the

ENSILAGE (*Continued*)—

conditions of the experiments being such as to make possible a fair comparison of the feeding values of the three types of fodder. The silage was of the "green fruity" type. In Table II. are given the results of the digestion trials, which were carried out on wether sheep.

TABLE II.—DIGESTION COEFFICIENTS AND STARCH EQUIVALENTS OF GREEN OATS AND VETCHES, OAT AND VETCH HAY, AND OAT AND VETCH SILAGE.

	Green Oats and Vetches.	*Oat and Vetch Hay.*	*Oat and Vetch Silage.*
	Per Cent.	Per Cent.	Per Cent.
Dry matter	63·7	65·0	64·1
Organic matter ..	65·5	66·1	65·9
Crude protein ..	63·1	68·2	65·1
Ether extract ..	51·9	36·8	73·4
Nitrogen-free extractives	76·5	71·3	70·5
Crude fibre ..	47·6	58·7	57·1
Starch equivalent per 100 lb. dry matter (lb.) ..	44·9	43·2	45·6

The data in Table II. in respect of the digestion coefficients of the organic matter indicate clearly that the green crop, hay, and silage are digested almost equally. So far as the digestion coefficients of the individual constituents are concerned, it is seen that there is no serious difference in the degree to which the protein of the three fodders is digested. In the case of the ether extract, the digestion coefficient is greatest in the case of the silage. It should be borne in mind, however, that the ether extract of silage is composed almost wholly of organic acids. The nitrogen-free extractives of the hay and silage are approximately of equal digestibility, and, in both cases, the digestibility is somewhat lower, but not to such an extent as was thought formerly, than that of the corresponding constituent of the green forage. The fibre constituents of the hay and silage are almost equally digested, and in both cases the fibre digestion coefficient is very significantly higher than the value for the fibre in the green oats and vetches. It is now recognized that the changes which occur in the silo and in the stack lead to a definite increase in the digestibility of the fibrous component of the crop.

The starch equivalents of the green fodder and the silage are almost equal, whereas the value of the hay is slightly inferior. This slight superiority of silage over hay has been confirmed not only by measurements of the metabolizable energy of the two fodders (Woodman, *J. Agric. Sci.*, xii., 144, 1922), but also by the results of long-period feeding trials carried out on the University Farm at Cambridge (Amos and Woodman, "Ensilage," Misc. Pub., *No.* 53, *Min. Agric.*, p. 45, 1926).

Losses of Nutrients during Ensilage—The losses of food material which always occur during the preservation of green crops in the silo are caused by (1) the respiratory activity of the plant cells during the early period of storage, (2) drainage of juice from the silo, and (3) the action of bacteria on the constituents of the crop. An attempt was made in investigations at Cambridge (Woodman and Amos, *J. Agric.*

ENSILAGE (*Continued*)—

Sci., xvi., 539, 1926) to measure the losses of dry matter in a number of regularly spaced layers of silage in a tower silo, the immediate object being to determine the *average* loss of nutrient matter in the entire mass of material. The work was continued over a period of two silage seasons, and the results which were obtained afforded strong disproof of the statement that the ensilage of green crops cannot be accomplished without large losses of food material.

The results obtained with crops containing from 26·5 to 33·9 per cent. of dry matter showed that "acid brown" silage can be made in the tower silo with an average loss of dry matter equal to about 6 per cent. of that contained in the green crop. It was shown further that "sweet" silage, if made under good conditions, can also be produced in the tower silo with an average dry matter loss of the same order. With "green fruity" silage, the average loss under satisfactory conditions of ensilage in tower silos is about 9 per cent. This somewhat higher figure is largely the result of the more copious juice drainage which accompanies the ensilage of the crop at the relatively early stage of growth required for the production of "green fruity" silage, although, as has already been pointed out, the superior nutritive properties of this type of silage compensate, in a large measure, for this disadvantage. Evidence was obtained in support of the statement that when a silo is filled with a crop of fairly uniform moisture content, the lowest losses of dry matter occur in the middle layers of the column of silage.

For the purpose of making silage of good quality, and at the same time of keeping down the losses to a minimum, the optimum dry matter content of the green crop appears to lie in the region of 30 per cent. When the crop at the time of cutting is wetter than is represented by this figure, it is desirable to allow a period of wilting, if weather permits, to enable the crop to attain a moisture content in the neighbourhood of 70 per cent.

The losses in the tower silo may be considerable when sappy or rain-laden crops are ensiled, owing mainly to the excessive drainage of juice from the silo under such conditions. With green maize, containing 16 to 18 per cent. of dry matter, the loss of dry matter may amount to 15 per cent. (Woodman and Amos, *J. Agric. Sci.*, xiv., 461, 1924). The ensilage of sugar-beet tops, containing about 17 per cent. of dry matter, is accompanied by a loss of about 28 per cent. of the food material (Woodman and Amos, *J. Agric. Sci.*, xvi., 406, 1926). If such succulent crops be ensiled during the autumn above a crop of silage made during the early part of the season, then the losses in the underlying silage may be augmented very considerably by the solvent action of the juice which drains down from the superimposed layer of succulent material.

H. E. W.

ERGOSTEROL—See Vitamin Requirements of Farm Animals, under Foods and Feeding.

ERGOT (in cereals and grasses)—See Diseases of Cereals, under Wheat; Seed, Transmission of Plant Diseases by.

FALLOW—In all arable cropping, land is fallowed at least once in the rotation by one or other of the following methods.

(*a*) Bare or summer fallow.
(*b*) Bastard fallow.
(*c*) Green crop fallow.
(*d*) Fallow crop.

Fallow is a word of Saxon origin meaning pale-yellow, and, therefore, when applied to farming, suggests bare ground. A fallow is used to both rest and clean the soil.

Bare Fallow—On heavy clay soils it is still customary to practise bare fallowing, though this method of cleaning is diminishing. A corn stubble which is to be bare or summer fallowed is not ploughed usually until about the end of April; the land is then turned over, preferably by steam or tractor power. The furrows are turned back about the end of May and left to dry for perhaps three weeks, when the land is cross ploughed. The result of the crossing is to break the soil up into large clods which by exposure to the sun become baked through, and the weeds are thus destroyed. The soil is moved at intervals throughout the summer to kill weeds and weed seeds as they germinate.

Towards the end of September cultivator and harrows replace the plough, and the soil is worked down to a tilth preparatory to sowing wheat. Bare fallowing is now so expensive that bastard fallowing is rapidly replacing it.

After harvest the corn stubble is ploughed and drilled with tares or winter tares and oats, which are either cut green or made into hay in June. The land is then ploughed up into rough clods and fallowed during July and August as for a bare fallow. (See Agriculture, Australia and Canada.)

Bastard fallowing is also a popular method of cleaning land after a crop of clover. As soon as the hay crop has been carted the land is usually pulled up by steam or tractor cultivator and left to bake through under the July sun. Bare and bastard fallowing are only effective on heavy land.

Green Crop Fallow—Green crop manuring (see Green Manuring) reduces the necessity for maintaining the land bare all the summer. Several crops of mustard can be grown and ploughed under during the season, forming an equally effective and cheaper method of cleaning the soil.

Fallow Crop—On the lighter classes of soil weeds are kept in control and fertility maintained by fallow crops, *e.g.*, turnips, swedes, kale, mangolds, etc. These are all crops which, when properly cultivated, check the growth of weeds and allow the soil to recuperate from the effects of growing exhaustive straw crops.

FARM ANIMALS, Vitamin Requirements of, and **Mineral Requirements of**—See Foods and Feeding; Metabolism, Mineral.

FARM CAPITAL—In this country, owing to the prevalence of the system of farm tenancy, it is customary to make a distinction between landlords' and tenants' capital. The first includes (apart from the capital

FARM CAPITAL (*Continued*)—

value of the bare land) fences, roads, drainage and water supply systems, growing timber, and all buildings of a permanent character. Tenants' capital includes work animals, machinery and implements, livestock, and floating or working capital. The broad principle is, of course, that the landlords' capital includes those items of equipment that are practically inseparable from the land, while the tenants' embraces whatever is easily movable. Obviously, there are forms of capital that do not fall definitely into either group. Stationary engines, threshing machines, and other fixed plant, wire fences, unexhausted manurial values, etc., are examples. Moreover, there is nothing inevitable even about the broad distinction that we make. For example, under the French system of métayage and the similar share-tenancy system of the United States, the landowner provides the whole, or practically the whole, of the farm capital. Even in this country there are many cases of an exceptional character. Thus, in certain parts of Scotland and the border district straw and also farmyard manure may be "steelbow," *i.e.*, may belong to the landlord and be handed over from one tenant to the next without compensation; in many districts certain acreages of roots, straw, and hay must be handed over at the end of a tenancy at a so-called consuming value, which bears no very close relation to market price; hence these items of capital belong to the tenant only in a partial sense. An exception in the opposite sense is provided by the "Evesham custom," under which fruit trees, etc., belong to the tenant. It will be clear that the capital value of a farm, or the capital required to stock it, cannot be accurately determined without a full knowledge of the local customs regarding tenant right as well as of the law of landlord and tenant.

Landlords' Capital—In the practice of land valuation no attempt is made to differentiate between the capital value of the bare land and that of the various improvements that have been made upon it. The valuer commonly asks himself, firstly, what annual rent the subjects would command if let by open competition to a substantial tenant; and, secondly, what would be the average outgoings (tithe, repairs, and maintenance, etc.). Deducting the latter figure from the gross rental, he obtains the net annual value, which is then capitalized at a certain number of years' purchase. The number of years' purchase may be said to average about twenty, but naturally varies according to current interest rates and also according to the amenities of the district. Prospective building or other development value, minerals, etc., are valued separately.

The proportion of the net annual value which represents true economic rent varies greatly. In the case of a permanent grass field, let without buildings and not artificially drained, the great bulk of the annual revenue is true rent. On the other hand, in that of an arable farm, reclaimed from bog or moorland, and well equipped with fences, roads, and buildings, the major part of the annual "rent" is not economic rent, but interest on the capital expended on improvements.

FARM CAPITAL (*Continued*)—

The problem arises, from time to time, of the advisability of investing further capital in the land, in the form of buildings or other permanent improvements. The test to be applied in such cases is whether the annual value of the farm will probably be increased by such a sum as will, after deduction of the amount required for maintenance or sinking fund purposes, return the ordinary rate of interest on capital. Thus, suppose that a particular field is estimated to have a rental value of 12s. per acre, and that the estimated cost of tile draining it is £12 per acre. Six per cent. may be taken as a sufficient return to cover interest and sinking fund; and this represents about 14s. 5d. per acre; hence, the question to be answered is whether the field, after it has been laid dry, is likely to be worth an annual rent of 26s. 5d. per acre, or more.

Tenants' Capital—Tenants' capital may conveniently be dealt with under the following three main heads:

(*a*) Work animals, harness, implements, and machinery.
(*b*) Livestock.
(*c*) Working or floating capital.

(*a*) Work Animals—Neglecting for the present the possibility of replacing horse by mechanical power, and taking the normal working team as a pair of heavy draft horses, the horse requirement may be calculated from a consideration on the one hand of the acreages of the various crops, the character of the soil, the method of disposal of the produce, etc., and, on the other hand, of the probable number of horse working days per annum. For example—the production of an acre of cereal crops, on medium soils, requires on the average about six horse days, while the production of an acre of roots requires on the average about fifteen horse days, and that of an acre of seeds hay about three horse days. Taking the simple case of a wholly arable farm of 200 acres, divided as shown, the horse working days can thus be roughly calculated:

120 acres cereals *c.* 6 horse days	720
40 acres roots *c.* 15 horse days	600
40 acres hay *c.* 3 horse days	120
	1,440

In the drier districts where such a farming scheme might prevail, the number of horse working days per annum may be expected to reach 200. Hence, the farm would be very adequately staffed with four pairs of horses.

In making such calculations as above, regard must be paid to a number of variables which may be shortly catalogued:

(1) Large farms, with from four pairs of horses or over, are generally more economical in the matter of horse labour than those of smaller size.

(2) Under the most favourable conditions (light soil, dry climate, and a varied cropping scheme) the number of horse days per annum

FARM CAPITAL (*Continued*)—
may reach 230; under the least favourable it may fall to 160, or occasionally still less.

(3) The horse labour per acre varies considerably in relation to the nature of the land. On heavy soils the requirements may be 20 or 30 per cent. greater than those assumed above, and conversely on light land they may be 20 or 30 per cent. less.

(4) Good land, highly rented, always tends to be more thoroughly and intensively cultivated than poor cheap land, and hence the number of horses maintained per unit area is usually higher in the former case.

The value, on a cost of production basis, of the average useful farm horse is probably about £50 at four years old, *i.e.*, when the animal is fit for full work. Thirty pounds per head is a fair average valuation for an ordinary lot of farm horses of mixed ages. In farm accounting, horses are usually depreciated on the assumption of a working life of ten years.

Tractors—On large arable farms where the soil conditions are suitable, it is generally economical to replace a certain proportion of the horses with a tractor or tractors. Under the most favourable conditions for tractor-working a third of the horse staff may possibly be replaced, on the basis of a tractor to every three horses. This necessitates a corresponding displacement of horse by tractor implements, but on the whole does not seriously affect the total capital involved in the equipment of the farm.

Field Implements—The list of implements required for a particular farm can be made up only after a full consideration of all the particular circumstances. The following is a fairly typical list of the more important implements for a 300-acre mixed farm employing four teams:

Ploughs, general purpose	4	Drill, root or general purpose
Ploughs, digging	2	Grass seed broadcast machine
Harrows, ordinary sets ..	4	Manure distributor
Harrows, light sets ..	1	Mower
Harrows, chain		Binders ..
Spring tined cultivators		Swath turner
Grubber		Hay sweep ..
Double mould board ploughs		Horse rake ..
Horse hoes		Carts (1 horse)
Rollers, flat		Carts or wagons (2 horse)
Rollers, Cambridge ..		Water cart .. ..
Corn drill		

The cost of such an equipment, along with the necessary small tools and harness, at current (1931) prices, would be approximately £700. Allowing for depreciation at a constant rate (which is generally based on a ten-year life), and assuming that each implement is used until its value is negligible, the normal implement valuation on such a farm would be about half the foregoing figure, or about £350.

Barn Machinery—It is difficult to lay down any principles of general application in regard to barn machinery. On farms with 200 or 300 acres of arable it is usually economical to instal a complete thrashing plant together with power machines for preparing foodstuffs. A

FARM CAPITAL (*Continued*)—
full-sized thrashing mill, with a suitable engine, together with an average installation of smaller machines, will cost (new) as much as £600.

Miscellaneous Equipment—Other standard equipment includes weighing instruments, stack and wagon covers, sacks, ropes, etc. For the dairy, churns, cooler, separator, sterilizer, cheese vats, etc., are necessary according to the method of disposal of the milk. The usual cost of dairy equipment, where hand milking is carried on, is probably about £3 per cow. Where milking machines are used the figure rises to about £7.

Small farms suffer under an obvious disadvantage in the matter of equipment, because for a considerable number of individual implements they do not provide full employment. For example, Vaughan (*J.R.A.S.E.*, vol. lxxxv), in his farm survey of an area of the Cotswolds, found the following figures for the various size groups:

Size Group.	*Number of Farms.*	*Average Size (Acres).*	*Output per Acre.*	*Implement Valuation per Acre.*
			£ s. d.	£ s. d.
Over 500	15	599	5 11 1	1 10 5
300–500	25	352	6 13 5	2 2 5
100–300	28	181	7 9 4	2 7 4
Under 100	16	63	9 11 11	3 0 2

(*b*) LIVESTOCK—The stock-carrying capacity of a farm is a somewhat indefinite conception, because the stock may be supported to a greater or less extent by the purchase of feeding stuffs. Poultry and pigs, especially, are kept so largely upon concentrated foodstuffs that the numbers to be maintained on a particular farm need bear no very close relation either to the area of land available or the system of farming pursued. With cattle and sheep, however, the bulk of the food material is usually home grown, and purchases of food material are only made with the object of producing an economical and well-balanced diet. Under the more intensive systems of animal production, *e.g.*, milk production, more latitude is possible; while under the least intensive, *e.g.*, mountain sheep farming, the head of stock is strictly limited by the home production of food.

The maintenance of the work animals may be regarded as a first charge upon the available supplies of food. Approximately, each horse consumes the produce of two acres of oats (corn), one acre of hay, one to one and a half acres of straw, and from half to one acre of average pasture.

Stocking of Pasture—In order to estimate the stock-carrying capacity of pastures it is necessary to estimate the food production per acre. It may be said that in an average season the richest British pastures produce rather over a ton of starch equivalent per acre—fully 2 tons of dry matter with a starch equivalent of about 50 per cent. The sort of pasture that is reckoned as good dairy land, or will fatten heifers

FARM CAPITAL (*Continued*)—

with the aid of a small amount of concentrate supplement, probably yields about 14 cwts. starch equivalent per season. From this there are all grades down to the poorest mountain grazings where the yield falls to 1 cwt. per acre, or less. In every case, excepting only certain types of very poor mountain pasture, the protein content of the grass is adequate for all purposes, and hence need not be separately calculated. It is true, of course, that the output of food varies from month to month. It reaches the peak probably from mid-May to mid-June, and thereafter falls off practically to zero by November. This difficulty cannot be adequately met by leaving a large growth unconsumed upon the ground, because if this is done the quality of the herbage deteriorates. It is therefore an advantage if the grazing area can be considerably increased from July onwards, by making use of the aftermaths of meadows and seeds fields. Failing this (especially in the eastern districts), it is well to have arable forage crops available for the latter part of the summer, or alternatively to reduce the stock, *e.g.*, by sale of lambs or fat steers, in June and July.

If now we translate food production into carrying capacity, we find that 2 tons of dry matter, containing 1 ton of starch equivalent, will provide a daily ration for 180 days of 25 lbs. dry matter and 12½ lbs. starch equivalent. This is a full ration for a fattening bullock, of 10½ cwts., sufficient to produce a live weight increase of 2 lbs. per day. Hence the ordinary definition of first-class pasture land as that which will feed a bullock to the acre without cake.

Other stock may be equated with feeding bullocks according to their food consumption. Milch cattle consume about 10 per cent. more grass than feeding bullocks, in proportion to their size. The requirements of young cattle may be calculated from Wood's graph of dry-matter consumption ("Animal Nutrition," p. 175) as follows, taking the requirements of the 10½ cwts. steer as one acre:

Live Weight (Cwts.).	*Acres per Head.*
9	0·88
8	0·82
7	0·75
6	0·66
5	0·60
4	0·50
3	0·42

For sheep the dry-matter consumption is relatively higher. The following figures are the approximate areas required per head, again assuming that the pasture is of the quality indicated:

Live Weight (Lbs.).	*Acres per Head.*
200	0·22
175	0·20
150	0·18
125	0·16
100	0·14
75	0·11
50	0·09

FARM CAPITAL (*Continued*)—

Winter Stock—The winter stock-carrying capacity of a farm depends primarily upon the duration of the winter—or more precisely the non-growing season—and upon the available quantities of roots, hay, straw, silage, and other winter foods. Under the least intensive systems of grass farming, *e.g.*, mountain sheep farming—the winter season is provided for mainly by leaving a certain proportion of the season's growth unconsumed at the end of the growing season, hay and other stores being available only for emergencies. In such cases the winter stocking is arranged entirely according to past experience of the land in question. At the other extreme are farms where the whole livestock is rationed throughout the winter.

The winter feeding period varies from under five months in the south-west of England to over seven in the north-east of Scotland. Taking an average figure of six months' winter keep, the following are examples of the allowances required for livestock of the more important groups; in each case it is assumed that the home-grown foods are supplemented by normal allowances of concentrates:

Dairy cows (10 cwts. live weight):

32 cwts. hay.
{ 22 cwts. hay. 44 cwts. roots. }
or { 11 cwts. hay. 11 cwts. straw. 66 cwts. roots. }

Fatting cattle (10 cwts. live weight):

{ 8 tons roots. 1 ton straw. }
or { 6 tons roots. ½ ton hay. 1 ton straw. }

Young cattle may be equated with mature animals according to the figures given above.

Arable land ewes, of 150 lbs. live weight, may be expected to consume about 30 cwts. of roots, or the equivalent of other forage crops, during the winter season, along with about 1 cwt. of hay.

(*c*) Working Capital—The working or floating capital comprises that which is regularly turned over, *i.e.*, realized, and again invested, the rate of turnover varying with the nature of the product. For a farmer entering a farm at Lady Day, it would include the compensation payable for the former occupier's tenant right, together with sufficient cash to cover the requirements of the farm (seeds, manures, feeding stuffs, labour, etc.) up till such time as the income might be expected to balance the expenditure.

Total Capital Requirements—During the long period of relatively stable prices which preceded 1914, £10 per acre was usually regarded as a sufficient capital for the ordinary type of mixed farm. This figure rose to over £25 per acre in 1920, and has since fallen to about £14.

The following are examples (Watson and More, "Agriculture," 2nd edit., 1928, Oliver and Boyd, Edinburgh) of the capital requirements of typical British farms:

FARM CAPITAL (*Continued*)—

I. East of Scotland farm of 300 acres, 280 arable, rented at 35s. per acre, and run on the East Lothian six-course rotation (oats, potatoes, wheat, roots, barley, seeds). Inventory made on August 1:

	£	£
Standing Capital:		
11 work horses at £30	330	
Field implements*	350	
Oil engine, thresher, and barn machinery*	400	
		1,080
Crop:		
40 acres wheat at £9	360	
60 acres oats at £9	540	
20 acres barley at £8	160	
40 acres potatoes at £20	800	
40 acres roots at £12	480	
40 tons hay at £3	120	
		2,460
Livestock:		
3 dairy cows at £30	90	
30 fattening cattle at £25	750	
100 store lambs at 40s.	200	
		1,040
Miscellaneous:		
Straw, feeding stuffs, unexhausted manurial values, etc.		500
Total capital		£5,080

II. Cheshire dairy farm of 220 acres, 60 acres arable, rented at 45s. per acre. Inventory made at March 25:

	£	£
Horses:		
4 at £30		120
Equipment:		
Field and barn implements	180	
Dairy equipment	200	
		380
Cattle:		
80 dairy cows at £25	2,000	
10 heifer calves at £4	40	
17 yearling heifers at £12	204	
17 two-year old heifers at £18	306	
2 bulls at £40	80	
Sheep:		
40 ewes and lambs at £4 10s.	180	
		2,810
Pigs:		
9 sows, 1 boar, at £8	80	
80 other pigs at £3	240	
		320
Poultry and Poultry Equipment:		
400 head	300	
Crops, tillages, hay, straw, roots, feeding stuffs, and residual values	500	
		800
Total capital		£4,430

* At half new prices.

FARM CAPITAL (*Continued*)—

III. Welsh mountain sheep farm of 1,300 acres carrying a stock of 550 breeding ewes, and rented at 2s. per acre. Inventory at September 30:

	£	£
Sheep :		
550 breeding ewes and gimmers at 30s.	825	
200 ewe lambs at 20s.	200	
11 rams at £3	33	
		1,058
Horses :		
2 light carters at £25		50
Cattle :		
8 three- and four-year-old heifers in calf at £22	176	
4 eighteen-months-old heifers at £15	60	
4 heifer calves at £7	28	
1 bull	30	
		294
Implements :		
2 carts, 2 sets harness, hay rake, etc.		140
Standing capital		£1,542
Floating capital (one year's expenditure)		500
Total capital		£2,042

IV. Semi-arable sheep and cattle rearing farm of 800 acres, 150 acres ploughed annually, rented at 17s. per acre. Inventory at May 28th:

CAPITAL.

	£	£
Standing Capital :		
7 work horses at £30	210	
Tractor and field implements	500	
Thresher, barn machinery, sheep dipper, and miscellaneous ..	500	
		1,210
Livestock :		
450 ewes with 675 lambs at £6 per couple	2,700	
160 ewe hoggs at £3 10s.	560	
7 rams at £10	70	
20 Galloway cows and calves at £24	480	
1 bull	30	
20 blue-grey yearlings at £15	300	
100 fattening cattle at £22	2,200	
		£6,340
Crops and Tillages :		
100 acres cereals at £7	700	
50 acres roots (seed and tillage) at £5	250	
50 acres grass seeds at £2	100	
		£1,050
Miscellaneous :		
Feeding stuffs, manurial residues, etc.		400
Total capital		£9,000

J. A. S. W.

FARMING COSTS AND ACCOUNTS—The Farmer's Viewpoint—Farming is still, in many of its forms, a craft. Over the greater part of Europe and Asia it is a peasant industry. Even where it is more highly organized the farmer frequently undertakes much of the manual work himself. Only in the comparatively limited areas where large-scale capitalist farming is found are the functions of the *entrepreneur* separated from those of the employed worker, and the separation is rarely complete.

As regards the ownership of the means of production, great diversity is found. In peasant communities the farmer may own both the land and the general farm assets in equipment and stock; on the other hand, he may be merely a working partner, owning but a share in the farm stock and crops, his part of the farm profits being, in the main, the reward of his labour and of the labour of his family. The larger farmer may be an owner-occupier or a tenant, and whilst, normally, he will be the legal owner of the farm equipment and floating assets, not infrequently his ownership of land or of stock will be subject to some form of priority granted in respect of advances received. According to his circumstances his personal earnings will represent, in varying proportions, the rewards of labour, of management, and of the ownership of property; his expenses will include or exclude, as the case may be, the costs of hired labour and of hired management, interest on mortgages or loans, the rent of land and of fixed equipment. Again, in different parts of the world, or even of the same country, farmers will set before themselves, as the goal of their ambitions, varying standards of life and of comfort.

The Meaning of " Cost of Production "—From these circumstances it will appear that the items of cost which enter into farmers' estimates of what it is worth while to incur, in expenditure or in effort, in order to obtain a certain value of produce for sale, may differ very widely. The peasant who hoards his savings feels little or no concern about the rate of interest earned on his capital; the small farmer, working entirely with family labour, is hardly affected by the level of wages; to the owner-occupier, who is not faced by a demand for rent each half-year, the annual value of his land is part of his income rather than of his outlays. *Farmers, variously situated in these respects, will attach the chief importance to those elements of cost which make some demand upon their liquid resources.* The aggregate amount of unpaid labour given to farm work and management, and the amount of personal property in land and stock devoted by farmers to obtaining a livelihood from the land, are very great. The rate of earnings achieved is not reckoned by the producers at so much per hour worked, or so much per cent. on the money invested, unless, indeed, they are using borrowed capital. The returns accepted as sufficient will depend upon the standards of work and of comfort to which they are accustomed, and upon the opportunities for employing their labour and savings in other ways. It seems to be the fact that peasant agriculture on the Continent of Europe and elsewhere, including also parts of Great Britain, is as yet but little influenced by standards of reward for the employment of capital and of labour set up in industries in which

FARMING COSTS AND ACCOUNTS (*Continued*)—

there is greater mobility of capital and personnel. On the other hand, there are other areas, particularly in Great Britain and America, in which the business organization of farming corresponds fairly closely to that of industrial enterprise, and depends upon hired labour and often upon borrowed capital, and there are many farmers who combine the functions of the dealer and merchant with the business of farm management. In Great Britain a higher level of agricultural earnings is demanded than in communities in which non-agricultural industry plays a less important part.

If, therefore, we would seek to compute farming costs, or to make comparisons between the costs of production of agricultural commodities produced both at home and abroad, it is necessary, as the first step, to inquire into the circumstances under which the farming is conducted, and to approach the question from the viewpoint of the farmers concerned. "Cost of production" does not mean the same thing to farmers in different circumstances.

The Meaning of "Profit"—This is equally true when we are concerned to compute the "profits" of farming. The meaning ordinarily attached to the term "profit" in this country, as applied to a business conducted by an individual who uses his own capital, is the income, available either for private use or for investment, derived by that individual from the business, after making provision for the maintenance of his capital. Thus it is the total reward that accrues from work, from managerial ability, and from the use of material resources which are the property of the individual. "Profit," so defined, is the amount with which a person who wishes to maintain himself and his family in comfort and to make provision for their future, is chiefly concerned. Now it is, of course, a fact that a great many persons do not own all the property they use in their business; they borrow money and pay interest for its use, or they hire the use of land or machines and pay a rent for them, just as they may hire labour to assist in the work. These charges must be deducted in computing the "profit" earned by the individual as a reward for his own enterprise and for the use of that part of the capital which is his own.

It is clear, then, that "profit," which is a composite thing, may be made up in quite different proportions of the earnings of manual labour, of managerial ability and of capital. This fact has tended to promote some confusion in account keeping. Because "capital" can, under some circumstances, be lent out at interest, the idea has arisen that if interest at, say, 5 per cent. on the farmer's capital be charged in the accounts, his earnings as a worker and manager can be separately stated. Or, again, it is assumed that the farmer's work is worth so much per year, and, by deduction, a sum is arrived at which is expressed as interest on the capital invested. Whichever course is adopted, the result is indefinite, and the returns expressed in either way very frequently compare unfavourably with earnings in other industries. Nevertheless, farming goes on, farmers continue to compete for land. It would seem, in fact, that the distinction between the

FARMING COSTS AND ACCOUNTS (*Continued*)—

earnings of the farmer's own activities and the earnings of his capital in the farm is a rather artificial one. Farming offers a means of life which demands work, enterprise and money in the same hands. The individual farmer's interest is to make the total return from his combined resources the greatest possible. He may be quite content with an aggregate return which, divided into two or more parts, might seem an inadequate reward for the use of each of the factors taken separately.

The Real Advantages of Accounting—Bearing these facts in mind, what practical ends can be served by account keeping and by the estimation of costs in agriculture? There are at least three points of view from which this question may be approached—viz., the individual, the comparative and the national. The first (A) envisages the internal problems of the farm economy: these are the concern of the individual farmer. The second (B) contemplates the creation of standards by which the efficiency of farm organization can be tested, and seeks a basis for comparisons between farm and farm: this is the viewpoint of the advisory officer or farm accountant. The third (C) seeks to understand the place agriculture occupies in the national economy: it is the view-point of the agricultural economist and of the statesman.

A. **Accounts as an Aid to Efficient Management**—The keeping of accounts is frequently approached with diffidence by the practical farmer; cost accounting with even greater hesitation, because the process is usually associated in his mind with detailed records and an elaborate analysis of his outlays, for which he has little time or inclination.

The reasons for this diffidence, apart from the fact that farming is an open-air job, are not far to seek. Account keeping is an affair of commerce and of manufacture. Where there is a rapid turnover of goods, where debts are incurred in small increments from day to day and are settled periodically, as in a grocer's business, where goods are made to order at prices based upon estimates of cost, as by a firm of engineers, accounts are inevitable. But with farming it is often different. Transactions may be infrequent; they are often settled by contra-account; income can rarely be predicted when expenditure is incurred; any considerable variation in the annual programme of activity is not possible. In the day-to-day life of the farm, in the domestic catering, and frequently, too, in the arrangements for labour services, the farm and the home are not distinct. There may not be a clear distinction between personal and business expenditure. Nevertheless, on the larger farms account keeping is the rule rather than the exception. The motive, however, is more frequently the presentation of statements for obtaining relief from income tax than to provide a means of controlling the farm business. At the same time the costs and returns of farming are subjects of perennial discussion. Accounts, suitably arranged and kept with simple and definite objectives, may, in fact, become records of great interest and value.

FARMING COSTS AND ACCOUNTS (*Continued*)—

The Uses of Accounts—Probably the greatest advantage of accounting is that it assists precise thinking about the farm business and promotes orderly methods in organizing it. The yielding capacities of live stock become facts rather than estimates, expenditure for a given end and the returns obtained become related quantities which can be examined and compared. Accounts may indicate sources of leakage or of waste; they may reveal with the necessary emphasis any disproportionate outlays incurred in producing the yields obtained; they may suggest sources of revenue that are insufficiently developed. The importance of accounts in these respects becomes greater as the farm business becomes larger or more complex. But they are no substitute for thrifty management, and are of more value to the thoughtful and scientific farmer than to the men who rely upon native shrewdness and who follow traditional methods.

It must be admitted, however, that the accounts of a single farm for a single year, even if profits are unsatisfactory, often give no very clear indications as to what action to take in order to effect improvement. Accounts become of greater value when they have been kept for a series of years, when they can be judged with proper regard to the effects of season and when trends in prices can be observed.

In well-ordered accounts regard is paid as much to quantities as to values. In the business of farming, both yields and prices are variable from causes beyond the farmer's control. It is necessary to try to distinguish between the effects of season and other uncontrollable factors, and the effects of causes which the farmer can modify at will. The questions relating to the individual farm business which accounts should answer readily and concisely are:

(*a*) What profit has been earned and is available for private use or for improving the farm equipment?

(*b*) Is there any waste in labour, power, or material on the farm?

(*c*) In what directions should the business be expanded or contracted in order to improve the returns in a normal season?

(*a*) *Accounts for the Computation of Profit or Loss*—For answering the first of these questions accounts of the simplest kind are required, and the answer can be arrived at in one of two ways. The first way is to compute how much one's cash and one's property in the farm have increased during the period, adding on the amount of money or produce actually withdrawn for personal use, and deducting any sums contributed to the business from private sources. The other is to compute the difference between farm revenue income and farm revenue expenditure, *i.e.*, between income and expenditure which is not on capital account. The combining of these two processes constitutes what is termed "double entry" accounting, *i.e.*, changes in the amount of capital are checked by comparison with differences between income and expenditure. In practice the computation is made very simply by taking inventories of the value of live and dead stocks at the beginning and end of the year, and by keeping records of cash receipts, expenses and balances, and of accounts outstanding. The stocks and balances are brought together into yearly "balance

FARMING COSTS AND ACCOUNTS (*Continued*)—

sheets " which reveal changes in the farmer's capital. The valuation of stocks at the beginning of the year is added to the cash expenditure and to any increase in the debts payable by the farmer, in a " profit and loss " or " trading " account, in which the total of these items is compared with the total of the cash received in respect of sales or of work done, plus any increase in the sums due to the farmer, plus the value of the stocks left at the end of the year. The profit earned or loss incurred is thus revealed, and this should be consistent with the change in the amount of the farmer's capital, after allowing for private additions or withdrawals during the year.

This work is well within the capacity of any intelligent farmer, though, unless trained in account keeping, he may require a little skilled assistance with the annual balancing. The ease with which the valuation is made depends chiefly upon the date selected. The best time, on arable farms, is usually that at which there is least to value on the farm, viz., in the spring, and on sheep-breeding farms, immediately after the flocks have been made up, viz., in the autumn.

The Basis of Valuation—Broadly speaking, the principles on which valuation for the determination of profit should be made are (i.) that things on the farm primarily for use rather than for early sale, *e.g.* implements, dairy cows, breeding ewes, should be valued at their cost, less any necessary allowance for depreciation; (ii.) things produced on the farm which are intended for sale, *e.g.* fat stock, potatoes in pits, or things which might readily be sold even if intended for use, *e.g.* threshed oats, should be valued at market prices on a conservative basis; (iii.) forage produced on the farm primarily for use, and for which there is not a readily available market, *e.g.* feeding turnips, straw, hay (this list will vary from district to district), should be valued, preferably at a uniform price per unit from year to year, at values not in excess of their replacement costs in a normal season; (iv.) purchased stores, *e.g.* feeding stuffs or artificial manures, at cost; (v.) growing crops and cultivations, either at the same amount each year, or at a price per acre which is kept constant from year to year, and which is not in excess of estimated normal outlays for labour, seed, and manures incurred up to the date of valuation; (vi.) farmyard manure, according to local custom at ingoing, either at a uniform price per ton or per cubic yard from year to year, or at a fixed sum, or at no value at all; (vii.) land in the occupation of the owner at cost, buildings at cost less depreciation.

The chief importance lies not so much in the basis adopted as in uniformity of procedure from year to year, with the proviso that fluctuating market values should not in any case be used for valuing the permanent equipment and breeding stocks.

These principles are clearly not applicable in their entirety to valuations made on taking or leaving a farm, when the selling value of everything on the farm is to be assessed; they are, however, suitable for making annual valuations for the determination of profit or loss during successive yearly periods.

FARMING COSTS AND ACCOUNTS (*Continued*)—

Account Books—The form of account book is not of particular moment so long as it is designed on correct principles. The method of analysis of income and expenditure may be either by a columnar form of cash book or a ledger. But books which do not permit of a regular balancing of cash received and paid, so as to check the sums in hand or at the bank, should be avoided, and books which make provision for entering against each transaction both quantity and value are to be preferred. A systematic check upon the quantities of stores and produce and upon the numbers of animals passing through the farm is, indeed, of the first importance in supervising the work of the farm.

(*b*) *The Avoidance of Waste*—On the larger farms, where the work of men and of teams may not be under the constant personal supervision of the farmer, simple records of jobs performed from day to day will assist him in keeping control of the efficiency of labour organization. Records of fuel used on motor vehicles and in power plant, and regular comparison with the distances travelled and work performed, will tend to prevent abuses, and allow loss of efficiency to be detected. But on farms of all sizes it is only by keeping the use and disposal of milk, grain, forage, and purchased foods under careful supervision that waste and loss can be avoided. Quantity is not always easy to estimate with accuracy, *e.g.*, it is easy to make mistakes in estimating the weight of hay in stacks, potatoes in pits, or corn in barns; but where measures can be applied it is always worth while to make use of them, and to record the utilization of available supplies. By this means a check upon rations fed to stock is obtained, losses due to vermin are assessed and can be combated, leakages due to dishonest practices can be discovered, and waste in all its forms avoided. This is particularly important on large farms, where the farmer must of necessity delegate responsibility to others. It involves but little additional trouble to record in the books of account quantities as well as values of things bought and sold, and to record in a notebook, kept in the barn or in one's pocket, the use of stores withdrawn for feeding stock, for sowing in the fields, or for family use. A regular tally of the numbers of livestock provides a check upon the accuracy and completeness of the entries of sales.

(*c*) The use of accounts for getting guidance as to the directions in which adjustments should be made to obtain better results may involve some analysis of income and expenditure. For practical purposes it is unnecessary to allocate all the expenditure on a departmental basis in search of the total costs of separate products. It is best to proceed by considering first what changes in the farm organization are possible, and then attempting to estimate what effect upon the net income such changes would have. Generally one or more of the following courses may be open to a farmer for the improvement of his income: (i.) to increase the value of his output by improving either the quality or the quantity of his produce: this will usually mean some addition to expenditure, *e.g.*, for manures or for better seed; (ii.) to reduce the current expenses without altering the system of farming:

FARMING COSTS AND ACCOUNTS (*Continued*)—

this will usually mean some reduction in gross return; (iii.) to add some sideline to the farm which may utilize spare time or by-products profitably, *e.g.*, poultry, bees, or pigs; (iv.) to increase the emphasis on particular crops at the expense of others which can be replaced; (v.) to substitute one class of stock for another without changing the general system of farming, *e.g.*, calving heifers for store bullocks; (vi.) to alter radically the system of farming by grassing down arable, or ploughing up grass land, or by taking up dairy farming in lieu of stockfeeding, and so forth.

In all of these cases, except the last, the experiment can usually be made on a small scale, and if this is backed up by sufficient accounts, the possibilities of success can be gauged. In the last case it will be necessary usually to proceed on the basis of estimates, drawn up, preferably, with the experience of others as a guide. We will return to this. For the less venturesome farmers, changes which can be made without altering radically the system of farming will be tried, and the records of trials in the favoured direction need not be elaborate. The simplest method of proceeding is to separate out for comparison only those costs which are increased or diminished by the change of method, and set against these the difference in return. Expenditure which is common to both methods can be left out of account. For example, the rent of the land, depreciation of buildings, and, in general, charges of an "overhead" character can be ignored. The primary object is to measure *extra* cost against *extra* return. Clearly, in all such cases it is desirable to record both quantity and value in respect of all items, since costs and returns will be influenced by price levels, and it is best to be able to state results in terms which can be interpreted as success or failure according to the state of the market. For a fuller discussion of accounting method see "Cost Accounting Applied to Agriculture," by J. S. King, Reading University Studies, Oxford University Press, xiii. and 182, 1927.

B. **Efficiency of Farm Organization**—Consideration of the more daring procedure of altering the general system of production brings us to a discussion of accounts from the point of view of the advisory officer, who is concerned with the giving of advice upon the use of land and of economic environment to the best advantage. For all such work it is very desirable to be able to refer to results obtained under conditions similar to those of the farm under review. There are many dangers inherent in making comparisons between farm and farm. This is particularly true in countries like our own, where physical conditions are rarely quite alike for farms separated even by short distances, and where size of farm, state of buildings, elevation of land, character of soil, and convenience of access to markets may impose minor, if not major, differences of organization and method upon the farmers.

The comparative study of farm accounts with a view to farm management control is of relatively recent development. Most has been done in the United States of America, where advisory service of

FARMING COSTS AND ACCOUNTS (*Continued*)—

this kind, based upon accounts kept upon a uniform system, has been applied with success. At the University of Illinois, for example, the method, in brief, is to present each farmer with a statement, in columnar form, in which the varying levels of net return earned on farms in the area are set against a number of indices of efficiency, *e.g.*, the number of acres worked per man or per horse, the returns in livestock produce per 100 dollars of food fed. The farmer's position, both as to profits earned and as to his efficiency under each of the headings specified, is indicated by drawing lines at appropriate points in the several columns on the chart. The farmer sees his points of weakness and of strength at a glance. This method of presentation seems to offer a reliable basis on which farmers, similarly situated as regards soil and situation, can profit by each other's experience.

On the continent of Europe, and especially in Germany, Switzerland, and Denmark, large numbers of farmers have kept books of account, under the supervision of central institutions or local societies, for some considerable period. In Germany the provincial centre is the office of the Landwirtschaftskammer (Agricultural Council), and it is the practice of these Councils to prepare annual summaries of the financial transactions of farmers in the province in tabular form, the farms being grouped according to district or type, and information is given relating to crops, receipts, expenses, and net returns in considerable detail. The chief objective in this work is, however, a fiscal one—namely, the presentation of results which will be accepted as satisfactory for the assessment of taxes. The extent to which the data may be used in giving guidance in the problems of farm management seems to depend upon the ability of the accounting officer at the bureau of the Council, and of the farmer himself, to interpret the comparative statements in terms of farm practice. For national statistical purposes representative accounts from the several districts have, in recent years, been summarized at the central accounting office of the Landwirtschaftsrat in Berlin. As a means for contributing directly to the solution of farm management problems, comparative study of the available accounting data does not seem to have received systematic attention; indeed, there is much difference of opinion in the agricultural colleges in Germany as to the effectiveness of accounts for this purpose.

In Switzerland, accounts are received for analysis by Professor E. Laur at the Secretariat of the Swiss Peasants' Union, Brugg, and they are made the subject of careful compilation for presenting the facts of the changing economic status of the agricultural industry in statistical form from year to year. But it is only very recently that it has been attempted to carry back to the individual farm a criticism of internal policy based upon comparative accounting data. In Denmark, too, there has been a widespread development of farm accounting, in which the principle of co-operative action through book-keeping societies has been applied. A national statistic based on selected examples has here, too, been created under the direction of Professor O. H. Larsen at the Bureau of Farm Management and Agricultural Economics, Copenhagen. Up to the present, the use of the data collected for

FARMING COSTS AND ACCOUNTS (*Continued*)—

throwing light on questions of internal farm management has been confined to the presentation of comparative accounts, relating to farms showing particularly good, or particularly poor, returns over a series of years.

In England, the main emphasis in economic advisory work has been placed upon the presentation of comparative costs of production, obtained from a few farms in each of the twelve advisory provinces. This method precludes any close contact with the main body of farmers, who can rarely benefit from the rather detailed results of farms which may not be representative of the districts in which they are situated. In Scotland, an attempt is being made to combine the preparation of an annual statement of the position of the agricultural industry as a whole with the creation of an advisory service for the promotion of the economical production and marketing of agricultural products. The *modus operandi* is to prepare a quantitative statement of the distribution of the various types of Scottish Agriculture, based upon statistical and other information, and then to obtain simple but adequate financial and quantitative accounts of the business of *selected sample groups* of farms. The co-operating farmers will benefit by being able to obtain comparisons with other farms similarly circumstanced and of similar size; the general body of farmers will have at their disposal an analysis of the factors making for success or failure in their own particular districts. This work is being undertaken by the three Agricultural Colleges at Aberdeen, Edinburgh, and Glasgow, in co-operation with the Department of Agriculture for Scotland.

The essential feature of any advisory service based upon accounts is that the facts presented must be comparable with one another. This can only be assured by grouping together farms which are similar in their circumstances and system of working, and offering comparisons between farms which, if not actually, are yet potentially, similar in their methods. For success in this work the financial results of the farms must be presented in a form which emphasizes the particular differences observed, and permits of an assessment of their effects. For example, on arable farms the weight given to the different saleable crops in the rotation, the yields obtained, the qualities produced as evidenced by the prices at which they sell, the amount of labour employed, are matters which will underlie differences in financial results; the livestock policy for the maintenance of fertility may also have important effects. On dairy farms the size of the herd, the yield of milk, the degree of dependence upon home-grown or purchased feeding stuffs, the proportional emphasis upon winter- and summer-milk production, may be among the more important factors. In framing the accounts to show where the differences in returns really arise, the points to be stressed must be borne in mind and data collected accordingly. It will rarely happen that the total costs of production of unit quantities of crops or stock will be required. These can seldom be determined without introducing a number of approximations, and when the best possible estimates have been made, unit cost may be irrelevant unless related to quantity produced. More importance

FARMING COSTS AND ACCOUNTS (*Continued*)—

attaches to the margin between the receipts and expenses of the farm enterprise as a whole, and to the relative sizes of the items of outlay and return that give rise to that margin. It may, however, be of value to trace and to compare the costs of alternative methods of conducting field operations, the outlays upon and yields from alternative systems of feeding livestock, the relative economy of alternative systems of labour organization, and so forth. The nature of these problems will normally be suggested by the differences observed in the financial accounts of farms in the same group. For their solution it may be necessary, in some cases, to obtain labour time-records, and to follow in some detail the use of foods of different kinds, or the application of manures to the land. But no very complete and balanced sets of cost accounts are necessary for these purposes. All that is required is to isolate the items of expenditure that vary in the alternative methods employed, and compare them with the returns obtained.

C. **Agriculture in the National Economy**—We have, finally, to consider how far accounting information can (i.) throw light upon the comparative costs of agricultural commodities produced in different countries which compete in the same market, and indicate the comparative profitableness of agriculture in different areas, and (ii.) assist in the formation of agricultural policy in a country. Some consideration has already been given to the first of these questions in the earlier paragraphs, in which the varying meanings which might attach to the concepts of " cost " and of " profit " were indicated. It seems to be clear that accountancy can, at best, offer very incomplete answers. " Cost " and " profit " have never in themselves absolute meanings; they are always relative to other conditions—to opportunities for spending, to standards of life desired by the producers, to the purchasing power of the money obtained by the sale of the commodities produced. None of these things is equal for different countries. While, therefore, money calculations may, in some cases, be made, in terms of the currencies of the several countries, and converted at any given time into the currency of some one country for purposes of comparison, to show at what price in each country respectively a commodity must be sold to obtain for the producers a monetary return sufficient to meet current outgoings and to provide the degree of comfort to which they are accustomed, the comparisons afforded by such calculations must of necessity contain many estimates, and they are approximately true only for the amount of produce obtained in the given period. If, following the usual conception of " cost," we do not include the rewards of the cultivators and the return upon their capital, both of these constituting the " profit " earned, our comparisons ignore those conditions which really determine the activity of the producers, viz., the capacity of agricultural production to afford them the livelihood they claim as a condition of producing.

Indeed, the price at which commodities are exported must, in the absence of bounties or their equivalent, be sufficient to include the profits of the cultivators, and these will naturally be as large as circum-

FARMING COSTS AND ACCOUNTS (*Continued*)—

stances will allow them to get from time to time. Thus it seems that it is hardly through the medium of accounts that the competitive strength of different countries in the markets for agricultural produce should be sought. The real test of any country's ability to compete abroad is the price at which a continuing supply of products is forthcoming. It is of interest to look behind that price to the conditions which make it remunerative to the producers, and here their accounts can assist, but a major element in the price will be the expenses of maintaining the standard of comfort achieved by the producers. Accounting, then, has only a secondary part to play in international inquiries of this kind. Its sphere is chiefly in the internal economy of the individual productive business and of the particular country in which the producers are situated.

There remains, then, the final question as to the uses of accounting data to the statesman in search of a practical policy towards agriculture. It is clearly of importance to know with some precision how those engaged in the industry are faring. There are indices, independently of accounts, to show how the fortunes of agriculturists in general are changing from time to time: index numbers of prices, statistics of wages, of employment, of the level of rentals, and other information collected by the Government Departments in most countries. But in areas where agriculture is not homogeneous these general indices do not give any very clear picture of rural conditions; their quantitative effect upon the earnings of groups of producers variously situated cannot be ascertained. To obtain this knowledge it seems necessary to select a representative sample of farms and study their capitalization, their outlays and returns, their dependence upon family or hired labour. Financial accounts which include quantities as well as values offer a ready means of access to these data. Moreover, from such accounts can be seen, not merely the present status of the industry, but the factors underlying changes that occur. Policy can thus be formulated with reference to the facts of the case. The extent of depression or of prosperity, the incidence of the effects of foreign competition, or of taxation imposed or remitted, can be ascertained; the potentialities of areas for development can be assessed. The picture of agricultural conditions presented through accounts discloses the state of individual well-being of agriculturists instead of being impersonal and general. In all countries in which agricultural development is deemed important for the maintenance of general welfare, the centralized collection of accounting data must find a place.

J. S. K.

FARMING SYSTEMS—The broad principles of farm organization may be briefly stated thus:

1. The farmer must decide upon the list of commodities that he will probably be able to produce, in competition with other farmers, at a profit.

2. He must endeavour to dovetail the various branches of his enterprise into a general scheme that can be economically run as a whole.

FARMING SYSTEMS (*Continued*)—

3. He must draw up his scheme in such a way that it may be adapted and modified, with a minimum of loss, in order to bring it into harmony with changing conditions.

The more important circumstances that must be taken into account may be briefly catalogued:

I. Natural Conditions—The rainfall, temperature, and other climatic conditions; the chemical fertility of the soil, its water-retaining powers, and the ease or difficulty of its cultivation; the water supply.

II. Economic Conditions—The supply and quality of the available labour; the prevailing wage rates; the nature of the markets, their distance from the farm, and the available transport facilities.

III. Political Conditions—Security of tenure; tariffs, subsidies, and guaranteed prices; legal regulations with regard to wage rates, etc.

IV. Private Circumstances—The size of the farm; the amount of capital at the farmer's command; the farmer's own special aptitudes and training.

With so large a number of variables it is not surprising to find an infinite variety of farming systems in any particular country. This variety may be illustrated, so far as England is concerned, by the agricultural statistics of a few counties. In the following table the acreages of the various crops and the numbers of the more important classes of stock are reduced to a common basis of 100 acres of crops and grass. Rough grazing is not included in the 100 acres, but the area of such land that goes with each 100 acres of crops and grass is separately shown. The figures are those for June, 1929:

	Cambridge (Isle of Ely).	*Norfolk.*	*Cheshire.*	*Northumberland.*	*Hants.*
Wheat	19	8	2	1	7
Barley	8	20	—	2	4
Oats	9	7	11	5	11
Beans and peas ..	3	1	0	—	—
Potatoes	17	2	4	1	1
Roots	3	12	2	4	8
Sugar-beet	10	5	—	—	—
Rotation grasses ..	2	13	13	10	12
Fruit	5	2	1	—	1
Miscellaneous crops ..	3	1	1	—	3
Bare fallow	1	2	—	—	4
Total arable	80	73	34	23	51
Permanent pasture ..	15	23	48	62	31
Permanent meadow ..	5	4	18	15	18
Rough grazing	1	7	4	80	21
Cows and heifers (in milk or in calf)	3	5	26	5	11
Other cattle	7	9	12	19	6
Total sheep and lambs ..	3	27	17	177	27
Total pigs	19	14	14	1	8

FARMING SYSTEMS (*Continued*)—

None of the above counties, of course, constitutes a homogeneous agricultural area. Yet the figures clearly show the importance, in the fen districts, of potatoes, wheat, sugar-beet, fruit, vegetables, and pigs; in Norfolk, the predominant position of barley and of the winter fattening of stock (the last can be inferred from the large root area); in Cheshire, the outstanding importance of dairying; in Northumberland, the concentration upon mutton and beef production; and in Hampshire, as a whole, the absence of any high measure of specialization.

It is impossible to discuss the principles according to which every detail of the farming scheme is to be determined, but one or two of the broader questions may be considered in detail, and some of the minor points touched on more briefly:

I. The Proportion of Arable to Grass.

(*a*) The gross output from the land, whether measured in terms of human food or in terms of money values, is greater from arable than from grass. At the same time, the expenditure, in labour, manures, seeds, depreciation, etc., is greater. In other words (despite the fact that grazing may involve quite as large or even larger capital outlays), arable farming is the more intensive system. Other things being equal, the more fertile farms, and those within easy reach of markets, have a high proportion of arable, while poor land in remote areas tends to be kept under grass.

(*b*) Soil texture and other factors influencing tillage costs are of prime importance. Heavy land, especially if it is indifferently drained, is costly to cultivate. On light land the individual tillage operations are more cheaply carried out, and do not require to be so frequently repeated. Moreover, free, well-drained soils are tillable during a very much larger number of days in the year, which gives greater economy of man and horse labour.

(*c*) Under the temperate conditions that prevail in Britain, the optimum rainfall for grass land is probably in the region of 40 ins. per annum. The corresponding figure for arable land is probably under 30 ins. Both figures, of course, vary according to the drainage and the water-retaining capacity of the soil. Hence, if we compare the rainfall map of the country with that showing the distribution of arable land, a marked negative correlation is found. The seasonal distribution of the rainfall is also a factor.

(*d*) Under all but the most extreme conditions summer pasture is a cheaper food for stock than arable forage crops. Conversely, the most economical winter rations can generally be obtained by using a certain amount of arable produce (roots, straw, silage, seeds, hay, etc.) rather than by relying entirely upon meadow hay. Hence, it is only under rather extreme conditions that either pasture or arable disappears entirely.

II. Alternate Husbandry.

Having decided upon a proportion of arable to grass, the question remains as to whether it will be more economical to make a permanent allocation of land to each division or to adopt a system of alternate

FARMING SYSTEMS (*Continued*)—

husbandry. On the one hand, land under alternate husbandry requires a measure of double equipment; it must be fenced and watered for grazing purposes; it must be fairly accessible to roads, and must be more thoroughly drained for tillage. Also there is the additional cost of periodical reseeding, the risk or failure of the seeds, and the further risk of insect damage to crops following the ley. On the other hand, at least in the cooler and moister parts of the country, seeds leys are substantially more productive than permanent grass. Thus it is not uncommon, where grazings are let by auction for the season, to find first year's ley commanding a premium of 50 per cent. and second year's a premium of half that amount, over permanent grass on the same class of land. Again, the estimated yield of seeds hay in England is about 29 cwts. per acre as against 21 cwts. for permanent pasture. In alternate husbandry there is the further advantage that the ley accumulates humus and nitrogen which are of great benefit to the succeeding arable crops. In times of rapid economic change the alternate system has also the advantage of elasticity, because merely by letting the leys lie, the grass acreage can be rapidly increased. (See Rotations.)

III. Complementary and Competitive Enterprises.

Complementary departments of the farm may be defined as those which are more economically run in conjunction than separately. A great mass of examples may be drawn from British agriculture. Cheese making and pig keeping form one such, because the most economical method of utilizing whey that has so far been discovered is that of feeding to pigs. Butter making and calf rearing are another pair of enterprises that are frequently run in conjunction. In this connection, too, it may be mentioned that one of the incidental results of the Cockle Park experiments was to show that a combination of sheep and store cattle produced a considerably larger output of meat per acre than either cattle or sheep alone. In connection with crops the classical example is that of the alternate cultivation of nitrogen-using and nitrogen-storing crops; this interrelation, although still of some significance, has lost part of its old importance owing to the large supplies of synthetic nitrogenous manures now available. Crops are to be regarded as complementary also in so far as they provide employment at different seasons of the year. Other aspects of the matter are dealt with under "Rotations."

As examples of competitive crops may be mentioned main crop potatoes and sugar beet, which both employ large labour forces at roughly the same periods of the year, and both respond profitably to applications of farmyard manure.

IV. The Level of Intensiveness.

Agriculture, it is well known, passes through alternate periods of prosperity and depression. The largest single cause of this phenomenon is variation in the general price level, due to changes in the quantity currency. If the amount of currency increases prices rise, and the first commodities to be affected are unmanufactured articles. The agricultural index figure, therefore, rises rapidly, while the increase

FARMING SYSTEMS (*Continued*)—

in the farmer's outgoings—wages, rent, farm requirements, living expenses, etc., is delayed. Conversely, when the general price level falls, agricultural produce is affected very quickly, while the fall in costs lags behind. It is also well known that agricultural production is subject to the law of diminishing returns. Hence, the highest profit is to be attained not by maintaining a constant output, but by intensifying production during periods of rising prices and by cutting expenses during the alternate periods of depression.

V. The Choice of Market Crops.

Wheat, potatoes, and sugar-beet may be selected as examples in order to illustrate the principles according to which the selection of market crops is made.

Wheat—*Climate and Soil*—Great Britain, as a whole, is comparatively ill-adapted to wheat cultivation. In most districts the rainfall, particularly in winter and in late summer, is too high and the amount of summer sunshine is too low. Many of our soils are too shallow or too light. It is only in the eastern and south-eastern counties of England that the natural conditions approach to those of the world's main wheat belt. (See Wheat.)

Markets—This country has, of course, a large wheat consumption, and the price of wheat is normally higher in Britain than in any other part of the world. In past times, when transport from the best of the world's wheat areas, *e.g.*, the black soil region of Russia and the American prairie, was slow and costly, the benefit of a near market was very considerable. Increasing home demands thus led to a marked expansion of the British wheat area during the eighteenth and the earlier part of the nineteenth century. With the development of steam ocean transport and the building of railways across the great continents transport costs fell greatly; hence for sixty years the wheat area in Britain, with only short-lived revivals, has declined.

Labour Requirements—The labour requirement of wheat and other cereals is comparatively low, and where cultivation is on a large scale, can be markedly reduced. A century ago the labour cost was reckoned at about ten man days per acre. Mainly owing to the invention of the string binder, the figure has been reduced to about six. With large areas under the crop and through the use of mechanical tillage, and the Combine Harvester, the latter figure may be further reduced to between two and three. It is obvious from the last consideration that large possibilities in the direction of reducing labour costs are open to the large farmer.

While there are minor advantages that still remain to the British farmer, such for example as the greater opportunities of utilizing straw, it must appear that, failing artificial measures to maintain the wheat area, the cultivation of the crop will only remain profitable on large farms in the eastern districts where the soil is really suitable.

Potatoes—*Soil and Climate*—The potato thrives under a wide range of climatic conditions. The frequency of late and early frosts is the main climatic factor limiting the distribution of the crop in Britain.

FARMING SYSTEMS (*Continued*)—

The cooler districts have the advantage of comparative freedom from Virus Diseases (*q.v.*), and in the drier districts the crop is freer from Blight. The crop is one requiring a high expenditure on labour and manure, and hence there has been a tendency for it to become localized in those areas where the yield is high. This depends mainly upon the character of the soil, the best being deep and free working loams. The heaviest yields are obtained on black fen land, and the finest quality from medium red loams. Clays and the chalky soils are the least suitable. (See Potato.)

Markets and Transport Facilities—The weight of marketable produce is from six to seven times as large from potatoes as from corn. The value per ton, at market, is normally from one-third to one-half that of corn. Thus, transport charges constitute a large proportion of the final cost, and proximity to markets and transport facilities have an important bearing on financial returns. Despite the presence of a large area of good potato land in Germany and Holland, and the advantage of cheaper labour in these countries, there are no regular importations except of "earlies."

Uncertainty of Returns—The variation in yield of the potato crop from season to season is rather high. According to the Ministry of Agriculture estimates the variation is about 50 per cent. greater than in the case of corn. Also, there is scarcely any carry-over from one year to the next. The result is that prices fluctuate violently from year to year, and these fluctuations cannot be predicted for more than a few months ahead. It does, indeed, appear that the acreage tends to diminish after two successive cheap years, but in the main the price is determined by the yield per acre. The following figures for the years 1906-13 show the close correlation between yield and price (Watson and More, "Agriculture," Oliver and Boyd, Edinburgh).

Year.	*Total Yield, Great Britain.*	*Average Price per Ton, First Quality, October to May.*
	Tons.	s. d.
1906	3,428	77 6
1907	2,977	94 0
1908	3,917	53 6
1909	3,674	63 6
1910	3,477	81 0
1911	3,825	74 3
1912	3,179	92 3
1913	3,865	69 3

The practical significance of these figures is twofold. In the first place a potato grower should be in such a financial position as to be able to bear a fairly heavy loss in a particular season; and, secondly, the farmer should increase rather than diminish his acreage after a season of low prices.

Labour Requirements—The labour requirement of the potato crop is very high, being approximately five times as high as that of a cereal. The seasonal distribution of the labour is also very uneven, unless

FARMING SYSTEMS (*Continued*)—

it is possible to grow early, second early, and late varieties in conjunction. The supply of casual labour is always an important factor, and sometimes the limiting factor in determining the acreage to be grown.

Manuring—The crop (except on fen land) responds to heavy dressings of artificial and of farmyard manure. Hence, where large acreages are to be grown the selling of hay, straw, and other bulky produce must be avoided in order that they may be turned into dung.

By-products—The crop always leaves for disposal a quantity of small and damaged tubers. Their most profitable utilisation is probably in pig-feeding, though they may be given to dairy or fatting cattle.

Sugar-Beet—This crop at present (1931) stands upon a different footing from other market crops, because it is subsidized. Also, it is grown on contract at a price per ton (of washed roots) which varies with the sugar content. Seed is supplied by the factory at approximately cost price, and producers have the option of receiving a stipulated quantity of pulp at a preferential price. (See Sugar-Beet.)

Soil and Climate—The crop succeeds well as far north as Yorkshire, but beyond this is not very reliable. The most favourable climate, as in the case of wheat, is that of the eastern counties. As long as the soil is not extremely heavy, is not sour, and is of good depth, satisfactory crops can be grown in the area indicated. The average British yield is between 8 and 9 tons net.

Proximity to the Factory is very important. A farmer within four miles of a factory might be able to transport his crop for 3s. per ton, while another at fifty miles from a factory and four miles from a station would pay approximately 10s. per ton. On a yield of 12 tons gross, the difference in net returns would amount to over £4 per acre.

Labour Requirements—The hand labour requirement is very high, and the time available for such operations as singling and lifting, if they are to be efficiently carried out, is short. The availability of sufficient labour at the seasons in question is therefore highly important.

By-products—Sugar-beet tops form a valuable food, both for cattle and sheep, during the early part of the winter. The average yield is of the order of 5 or 6 tons per acre, and the feeding value is somewhat higher than that of swedes. (See Feeding Stuffs.)

The beet crop can be produced in England at a cost not much exceeding 40s. per ton, net weight, on the farm. The value of the by-products and residues reduces this figure to perhaps 36s., to which again must be added the cost of transport to the factory. The cost of production depends largely on the wage rates for agricultural labour, which in this country are substantially higher than in the continental beet-growing countries. It has been calculated that, apart from the subsidy, the price that the factories could have afforded to pay, in recent years, would not have exceeded 25s. per ton. Unless, therefore, some substantial progress be made in the development of machines for handling the crop, it appears that the British industry will scarcely

FARMING SYSTEMS (*Continued*)—

be able to survive the withdrawal of the subsidy. It would also appear that tropical cane-sugar growers are in a position to produce sugar more cheaply than even the most favourably situated beet growers.

VI. Some Livestock Enterprises.

Milk Production—*Soil and Climate*—Since pasture affords much cheaper keep for cows than arable crops and purchased concentrates, the lowest costs of milk production occur in areas where the grazing season is long, and the grazings are reliable. This implies a soil of a fairly retentive character, and a climate with a rather high and well-distributed rainfall and a mild winter. A considerably enhanced price is usually obtained if the supply of milk is kept at a uniform level throughout the year, which involves the maintenance of a fairly constant head of cattle and the provision of full production rations for all seasons of the year. Hence the provision of supplementary foods, during periods of summer drought and of roots, hay, silage, etc., for winter feeding must be arranged. (See Dairying, and Milk.)

Markets—The production of milk for direct sale is confined to districts within fairly easy reach of markets. At one time the difficulty of transporting milk in fresh condition was so great that a large proportion of the supply was produced in towns and cities, feeding stuffs being transported thither from the farms. Recent developments —cleaner methods of production, more efficient cooling, and improved speed of transport—have greatly extended the milk-producing zones; but it is still true that the more distant areas have to bear an additional charge of as much as 2d. per gallon, as compared with the most favourably situated farms. Proximity to markets opens up to the farmer the further possibility of a retail trade. It seems unlikely that overseas supplies of fresh milk will ever seriously compete with the home product, but imported, dried and condensed milks enter into competition. In many districts milk is produced on yearly contracts at pre-arranged prices per gallon for each month. In the period of falling prices during which this system has been in operation it has proved beneficial to the farmer. In the period 1925-30 the price of milk fell from 71 to 58 per cent. above that for the period 1911-13, while the general agricultural index figure fell from 62 to 35 per cent.

Labour.—Dairying, unlike most live-stock departments, has a high labour requirement, an average figure in hand-milked herds being about twenty-four man days per cow per annum. The large staff required for milking is only so employed for two or three hours per day, and it is sometimes difficult to arrange for economical employment during the remaining working hours. In some districts it is possible to employ part-time women workers for milking only. Milking machines reduce the labour for milking, in large herds, by approximately two-thirds.

Milk production requires closer supervision than many other enterprises, and is not suited to occupy a minor place in the farm economy.

FARMING SYSTEMS (*Continued*)—

It tends rather, where it is taken up at all, to become the main department of the farm.

Cattle Fattening—The *summer fattening* of cattle tends to be concentrated upon the richest classes of grass land, where full production can be obtained during the greater part of the season without the use of cake. The difference between first and second quality pastures is much greater when measured in terms of fat production than when measured in terms of milk or growth. The finest fatting pastures are situated on chemically rich land, often of alluvial origin, where there is a good supply of subsoil water and a rather high amount of sunshine. The business employs a large amount of capital during the grazing season, but very little labour. Returns depend mainly on the relative prices of store cattle in spring and of fat cattle in summer and autumn, and the business is therefore of a highly speculative character.

Winter fattening is largely confined to the better arable districts. It provides on the whole the most convenient method for the disposal of straw, and its conversion into a good quality of farmyard manure. In the past the production of winter beef in Britain has been very large, and there has often been an insufficient margin between the price of store cattle in autumn and that of fat animals in spring. With the decline in the arable area, and in particular of the root area,

to the district in which the crops are grown. The high nutritive value of these commodities in the north-east of Scotland constitutes one of the main reasons for the prominence of winter cattle feeding in Aberdeenshire and the adjoining counties.

Pig Keeping—The British farmer, owing to regulations made for the prevention of disease, has a practical monopoly of the home market for fresh pork. He is also within easy reach of supplies of milling offals and other by-products which are largely used in pig-feeding. Among farm by-products unmarketable potatoes, whey, and skim milk are valuable pig foods.

Returns from pig keeping tend to fluctuate very greatly. Owing to the relatively quick rate of reproduction numbers increase very rapidly during periods of high prices, resulting in serious over-production; this in turn leads to curtailment of breeding operations and a resultant scarcity. The cycle of prices is ordinarily completed in about four and a half years. The demand for pork is also seasonal in character, reaching its highest in December and January, and its lowest in July. These circumstances must be borne in mind in organizing pig production. An exceptionally serious risk in the pig industry is that of swine fever, against which it is, however, possible to insure.

The pig industry can be very economically conducted upon a small scale, and with labour other than that of able-bodied men. Hence, it is a very suitable business for the smallholder.

FARMING SYSTEMS (*Continued*)—

VII. The Provision of Winter Food for Stock.

In the following table the food values, in hundredweights of starch equivalent and protein equivalent per acre, have been calculated for average yields of the more important crops used for winter feeding. The total production of dry matter per acre is also stated, and the ratio of starch equivalent to dry matter. The last figure has occasionally an important bearing on the practical use of the material, because it is essential to maintain, for each class of stock, a due balance between bulk and energy value.

Production of Food Value per Acre.

	Dry Matter.	*Starch Equivalent.*	*Protein Equivalent.*	*Starch Equivalent as Percentage of Dry Matter.*
	Cwts.	Cwts.	Cwts.	Cwts.
Turnips (15 tons) ..	26	15	1·2	58
Swedes (14 tons) ..	32	20	2·0	61
Mangolds (19 tons) ..	50	26	1·6	53
Cabbage (25 tons) ..	55	35	4·4	64
Silage (8 tons) ..	48	21	2·6	43
Meadow hay (22 cwts.)	18	7	1·0	37
Clover hay (30 cwts.)	25	10	2·0	38
Oats grain (14 cwts.)	12	8	1·0	70
Oats straw (22 cwts.)	19	4	0·2	21
Oats, total crop (36 cwts.)	31	12	1·2	—
Beans grain (16 cwts.)	14	11	3·2	76
Beans straw (24 cwts.)	21	5	0·4	22
Beans, total crop (40 cwts.)	35	16	3·6	—

These figures would not, of course, apply to the particular farm. The individual farmer must consider what yield of the various possible crops he may expect to obtain, over an average of years, and at what cost. He must then decide upon his scheme of food production, bearing in mind the particular needs of his stock and the relationship between his feeding crops and the other elements of his system. It is well, of course, to distribute risks. Thus, the yield of roots is greatly affected by the rainfall distribution of the particular season, and the quality of hay by the weather encountered during the haymaking season.

J. A. S. W.

FARMYARD MANURE—See Fertilizers.

FARMYARD MANURE, SYNTHETIC—See Fertilizers.

FATS—Chemically, the fats, whether animal or vegetable, are the glyceryl esters of higher fatty acids. The line of division between fats and fixed oils (see Oils) is not fast, depending merely on the physical condition; thus, a substance like butter fat may be regarded as a fixed oil in warm climates.

FATS (*Continued*)—

The chief fats with which the British agriculturist is concerned are beef and mutton fats, which consist for the most part of glyceryl esters of palmitic and stearic acids, with about an equal proportion of oleic (unsaturated) esters, especially in the product of Australian animals. Lard, the rendered fat of pigs, contains appreciably more of the unsaturated components and much less stearine. It will be clear from what follows, however, that the composition even of a particular variety of fat is not by any means absolutely constant. Finally, milk fat should be mentioned; this contains about as much oleic acid as beef and mutton fat, but very little stearic and only about half as much palmitic. The remaining fatty acid ingredients are lower members of this series: myristic, lauric, butyric, caproic, caprylic, and capric in order of importance. Hence the content of volatile fatty acids enables butter to be distinguished from margarine.

In plants, fats tend to accumulate chiefly in the seeds, *e.g.*, the brazil nut contains 70 per cent. of fatty material. Haas and Hill consider, however, that fat may well prove to be present in at least small amounts in all living cells. The vegetable fats are mostly fixed oils, but cacao butter and the fats of myristicaceous seeds are solid.

It has been stated (see Digestion) that ingested fats are hydrolysed in the gut of animals and then resynthesized in the intestinal villi, and this fat is frequently laid down, *i.e.*, stored in the tissues in the form, or more or less the form, in which it is digested (*see* Lebedew, *Zentrbl. med. Wiss.*, xx., 129, 1882). Clearly, however, the animal must have other sources of fat, and plants, naturally, cannot store it in this way. Before the historic experiments of Lawes and Gilbert at Rothamsted (*B. A. Reports*, 323-353, 1852), the old theory of Voit that the principal source of fat in the animal organism was protein obtained practically universal credence despite the later abandonment of the idea by its author. It is now clear that while formation of fat from the deaminated breakdown products of proteins is not impossible—is, indeed, quite likely to a small extent—the bulk of the fat reserves of both plants and animals comes from the simple carbohydrates in their tissues. The chemical process of fat synthesis in the animal organism was shown by Smedley and Lubrzynska (*Biochem. J.*, vii., 364, 1913) to consist, at any rate in part, of a building up of carbon chains by a series of aldol condensations beginning with a condensation of a molecule of acetaldehyde with one of pyruvic acid, thus:

$$CH_3CHO + CH_3CO.COOH \rightarrow CH_3CH{=}CH.CO.COOH + H_2O,$$

this keto-acid being reduced to the corresponding aldehyde, in this case aldol, by some other process, probably enzymatic. The aldehyde so formed can then condense in a similar way with a further molecule of pyruvic acid. von Euler (*Pflanzenchemie*, iii., 212, 1909) had previously rendered probable the existence of a similar process in plants, beginning with two molecules of acetaldehyde which yield aldol directly by condensation; this, condensed with a third molecule of acetaldehyde, yields sorbinaldehyde, which is actually found in small quantities in

FATS (*Continued*)—

plant tissues. Three such molecules condensed produce a substance which passes easily to stearin and linseed oil.

The storage of fat seems to be a process which is set in motion in some way by cold. Of this fact we have at least two notable instances —namely, the fat storage which proceeds so rapidly in hibernating animals on the approach of winter, in which respiratory quotients (see Calorimetry, animal) approaching 1·4 may be observed, and the great increase in fat content of the tissues of oil-bearing plants like the olive (Rousille, 1878) when the cooler days of autumn begin.

Respiratory quotients are observed in plants during fat storage to be well above unity, and during germination, when the fat is used up, they fall well below unity, forming a complete parallel to the same processes in the animal organism. Indeed, if this were not so it would be necessary to effect a radical revision of the theories of nutrition in this respect.

Tuttle (*Ann. Bot.*, xxxiii., 201, 1919) has definitely proved that accumulation of fat in the leaves of certain evergreens is caused by cold, by causing a reversal of the process in species of *Linnæa, Pyrola,* and *Picea* under fully controlled experimental conditions.

Fats in the animal body and in seeds are the chief means adopted for storage of energy, any lubricant function being entirely subordinate. For this purpose their chemical constitution is well suited, since they are able to yield approximately 9·0 calories of metabolizable energy per gram against the 4·1 supplied by protein and carbohydrates to carnivora and 3·7 for carbohydrates to herbivora. The fat in seeds and eggs supplies energy for germination and growth, in which it is largely consumed. Voit has shown clearly (*Zeit. f. Biol.*, xli., 545, 1901) that it is the fat reserves which enable an animal to continue to live through a period of starvation, and that the length of time for which an animal can live under such circumstances is dependent upon the extent of its fat reserves.

The processes of breakdown of fats in the organism whereby they are converted into carbohydrates, chiefly dextrose, is by no means fully understood. It appears to be reconverted into "soluble fat" passing through the walls of the cells of the adipose tissue, possibly by enzymatic hydrolysis. Glucose may then be produced from the glycerol. The higher fatty acids are almost certainly oxidized on the β-carbon atom with production of carbon dioxide, water, and a fatty acid containing two less carbon atoms which may then undergo a similar oxidation. This does not explain the oxidation of propionic acid which nevertheless goes on in the body. Dakin (*J. Biol. Chem.*, lxvii., 341, 1926) considers that this may occur by $\alpha\beta$-dehydrogenation with formation of acrylic acid, which is known to pass to glucose by way of lactic acid in certain conditions. He obtained no evidence of this, but an analogous oxidation of succinic acid to fumaric goes on in muscle.

Fat ingested in large quantities is able to raise the metabolism of an animal—that is, there appears to be a certain amount of thermic energy in fat as such, as in protein, but in all normal feeding experi-

FATS (*Continued*)—

ments this is vastly complicated by the fact that fat ingested reduces protein metabolism, and that, in short, "allowing for the difference in specific dynamic action, protein and fat replace each other in metabolism in isodynamic quantities" (Lusk, "Science of Nutrition," p. 318, 4th edit., 1928).

Another not unimportant function of fats both in plants and animals is the provision of a small amount of water to the organism during its katabolism which may possibly serve to minimize loss of moisture under conditions of water shortage. The amount of water produced per gram by fats is naturally greater than that from carbohydrates in virtue of their greater proportionate hydrogen content. (See Milk, Nett Energy Values, etc.)

FEEDING STUFFS—The problems relating to the economic feeding of farm animals have been dealt with in the article "Foods and Feeding, The Scientific Aspects of."

It is the purpose of the present article to give a summary of the feeding stuffs available for use on the farm, and to call attention to their main features in respect of composition, nutritive value and manner of utilization. It is proposed to follow the usual custom of dealing with them under the several headings of coarse fodders, green fodders, succulent foods, concentrated foods, and miscellaneous by-products of industries concerned with the preparation of foods for human consumption.

THE COARSE FODDERS—The feeding stuffs in this group are characterized by their high content of fibre. They are of a bulky nature, and are sharply contrasted in this respect with the concentrated foods, which contain high feeding value in small bulk. Generally speaking, the coarse fodders are used to supply the whole or part of the maintenance requirements of farm animals. Their bulkiness gives the animal the desired sense of repletion after feeding.

Straw—The straw of cereals constitutes a very bulky fodder, rich in indigestible fibre and containing very little oil or protein. It contains a high percentage of ash, which, however, includes an abundance of useless silica, and is poor in lime and phosphate. The feeding value of straw depends primarily on the stage of maturity of the cereal at harvesting, since the process of ripening is essentially one of transference of food nutrients from straw to grain. For this reason, **oat straw** has a higher nutritive value than either wheat or barley straw, as oats are commonly cut, especially in Scotland and the north of England, before they are completely ripe. **Wheat straw** is more useful for litter than as a feeding stuff. When employed for feeding purposes, it should not be chaffed, but fed in the long condition, so that the animal is able to pick it over and select the more nutritious and palatable portions. Barley is carried to full ripeness, and **barley straw** consequently is poor in feeding value, but in practice is frequently enriched by containing a proportion of the leaves and stems of rota

FEEDING STUFFS (*Continued*)—

tion grasses and clovers which have been sown with the crop. **The straws of the pea, bean, and vetch** are also used for fodder, pea-straw having the best feeding value and vetch-straw the poorest. Their value as food is greater when the crops are cut at an early stage.

Chaff and Cavings—These are by-products of thrashing. The cavings are composed mainly of the breakable leaves and, if rich in clover, have a fair feeding value. Chaff is frequently soaked with pulped roots before use to increase palatability, and also to avert risk of irritating the eyes of animals, which is liable to occur if it is fed alone.

Meadow Hay—This is the most important of the roughages. Its composition is extremely variable, the protein content varying, according to quality, from 7 to 12 per cent. It is a bulky fodder like straw, and may contain from 20 to 33 per cent. of fibre. It contains a fair proportion of ash and only a small amount of oil. The causes of the variation in the composition of meadow hay are threefold: (1) Botanical composition. In general, the greater the content of clover, the higher is the nutritive value of the hay, and the richer it is in lime and protein. (2) Weather conditions at time of hay-making. Rain leaches out some of the soluble food nutrients of the hay and lowers its feeding value, the effect being most marked if bad weather sets in just before the hay is ready for carting. (3) Date of cutting. (See Foods and Feeding.)

"Seeds" Hay—This is made from a mixture of clover and grasses grown on arable land. Its composition, as distinguished from that of meadow hay, depends on the proportion of clover it contains, the higher content of clover leading to an increased content of lime and protein. As in the case of meadow hay, its digestibility depends upon the time of cutting.

Clover Hay—Hay made from pure clovers, such as red clover or crimson clover, contains a higher percentage of protein than either meadow or "seeds" hay. An average sample of red clover hay contains nearly 14 per cent. of protein.

THE GREEN FODDERS:

Pasture Grass—See Foods and Feeding.

Lucerne or Alfalfa—This leguminous forage crop is of importance on account of its heavy-yielding and drought-resisting characteristics. It is rich in protein and in lime salts, and is relished by cattle, sheep, and pigs, though animals should never be permitted to eat it to excess. Lucerne is sometimes grown for hay, although this is liable to entail considerable losses of nutrient food owing to the foliage breaking off during handling. It is much more useful when grown as a soiling crop, and in this way it may yield as many as four "cuts" in a season. It is valuable as a supplement to pasturage in a droughty season. (See Lucerne.)

Sainfoin—This is a valuable leguminous crop for sheep, and contains about 80 per cent. of moisture and 3·5 per cent. of protein. When

FEEDING STUFFS (*Continued*)—

grown for hay, it should be cut during the early flowering stage to secure the maximum feeding value. (See Sainfoin.)

Red Clover and Crimson Clover—These protein and lime-rich crops afford good sustenance provided they are eaten in the flowering stage. After flowering, the leaves tend to drop off and the stems decrease in digestibility.

Vetches or Tares—This crop is usually grown in admixture with cereals, such as oats, barley, wheat, or rye, particularly the last-named, or with other leguminous plants such as peas and beans; such mixtures have become the typical silage crops of this country. When grown alone, the green crop may be cut and fed in the fresh condition to all classes of farm animals. It is a valuable source of protein and lime. (See Vetches; Ensilage.)

Green Maize—Only in the southern counties of the British Isles is it possible to grow maize to the desired stage of maturity for purposes of ensilage. It is mainly grown for feeding as a green fodder to dairy cows, and is specially useful for this purpose on account of its high-yielding characteristic. It is less rich in protein than grass and the leguminous crops, and, when fed to dairy animals, care should be taken to supplement it with food rich in protein. (See Maize.)

Silage—See Ensilage.

Sugar-beet Tops—See Foods and Feeding.

Rape and Mustard—These are usually grown as catch crops, and sheep are commonly folded on them. They contain about 85 per cent. of moisture and 3 per cent. of protein.

Marrow-stem Kale—This is a valuable crop for dairy cows during November and early December. It contains about 86 per cent. of water and 2·4 per cent. of protein. (See Kale, Marrow-stem.)

Cabbage—These constitute a useful supplement in the later stages of the grazing season. They contain 85 to 88 per cent. of moisture and 2·5 per cent. of protein. Dairy cows may receive up to 60 lbs. daily, per head.

THE SUCCULENT FOODS (ROOTS AND TUBERS)—The introduction of root crops into this country during the eighteenth century led to such widespread and permanent improvement in the methods of crop and animal husbandry, that it is surprising to learn that a school of agriculturists should have arisen to advocate the entire omission of root crops from the winter rations of dairy cows. The controversy which has raged round this question, however, has served to clarify the position, and the general opinion, supported by the results of practical trials, is that good results are obtained from the use of roots when they are fed to dairy cows in moderation, say 30 to 50 lbs. per day. It should be borne in mind that roots during winter are the most important source of the antiscorbutic vitamin C.

Roots are essentially succulent foods, the dry matter content of

FEEDING STUFFS (*Continued*)—

mangolds, for instance, varying between the limits of 9 and 14 per cent. Swedes contain about 11·5 per cent. of dry matter, but sugar-beet is outstanding with about 25 per cent. Almost two-thirds of the dry matter of roots consists of sugars, the rest being composed of pectose and small amounts of protein, ash, and fibre.

Sugar-Beet, Wet and Dried Sugar-beet Pulp, Molasses—Sugar-beet Pulp—See Foods and Feeding.

Mangolds—On an average, mangolds contain about 88 per cent. of moisture, 9 per cent. of carbohydrate (mainly cane sugar), and only 1 per cent. each of crude protein and fibre. The crude protein is largely in the form of simple nitrogenous substances such as asparagine. They are never fed immediately after lifting owing to their " scouring " action, due to the presence of small amounts of nitrate, but are allowed to mature in the clamp until after Christmas, when they may be fed without harmful results. During storage much of the cane sugar undergoes inversion into reducing sugars. Owing to the presence of an oxidizing enzyme, the juice of the mangold rapidly darkens on exposure to the air. Unlike turnips and swedes, mangolds are not liable to cause tainting of the milk of cows receiving them, and for this reason they are a favourite succulent food for dairy cattle. They may also be given to ewes and lambs in spring-time, but excessive feeding of mangolds to male sheep is inadvisable because of the risk of deposition of urinary calculi. Mangolds are also utilized efficiently by swine. (See Mangolds.)

Turnips—The white turnip contains about 8 per cent. of dry matter, of which rather less than 6 per cent. consists of carbohydrate. The yellow turnip is somewhat richer, containing from 9 to 11 per cent. of dry matter. As turnips are liable to cause a taint in milk, they should be fed after, and not just before, milking. (See Turnips and Swedes.)

Swedes—Swedes contain about 88 per cent. of moisture and rather more than 8 per cent. of carbohydrates. They possess, therefore, a higher feeding value than turnips. They store more satisfactorily than turnips on account of their harder texture. Like turnips, they are apt to produce a taint in milk, and should therefore be fed after milking. (See Turnips and Swedes.)

Carrots—Carrots contain about 87 per cent. of moisture and 9 per cent. of carbohydrate. They are relished by all classes of stock, particularly horses. Their feeding value is somewhat superior to that of mangolds.

Parsnips—Though not commonly used for stock in this country, parsnips are a useful food for dairy cows and bullocks. They contain as much as 15 per cent. of dry matter, including rather more than 11 per cent. of carbohydrate.

Kohl Rabi—It is customary to class kohl rabi with roots, though actually it is not a root but a swollen stem. It may advantageously be used for dairy cows, since it does not cause tainting of the milk. It has the further advantage of being ready for use immediately after

FEEDING STUFFS (*Continued*)—

cutting. Its dry matter content is about 13 per cent., including nearly 9 per cent. of carbohydrate.

Potatoes—This important tuber differs from roots in that its reserve carbohydrate is mainly in the form of starch instead of sugar. It is rich in food material, containing as much as 24 per cent. of dry matter, including 2 per cent. of crude protein, 0·1 per cent. of oil, 20 per cent. of carbohydrate, 0·9 per cent. of fibre, and 1 per cent. of ash. Raw potatoes may be fed in limited amount to all kinds of stock, and 1 lb. of potatoes may be regarded as equal to 2 lbs. of swedes or mangolds. For pigs, however, it is customary to cook them before use; 4 lbs. of cooked potatoes are equivalent to 1 lb. of meal. (See Potato.)

Jerusalem Artichoke—The artichoke is usually grown in this country for human consumption, but a small surplus frequently remains over for feeding to pigs and, less commonly, to cattle and horses. The tuber contains about 20 per cent. of dry matter, including 17 per cent. of carbohydrate and 1·5 per cent. of crude protein. The carbohydrate is present in the form of inulin. (See Artichoke.)

THE CONCENTRATED FOODS:

(*a*) *The Leguminous Grains.*

Beans—Beans are a popular food for farm stock. In the form of *meal*, they are a common ingredient of the pig's dietary and are reputed to produce an excellent quality of fat and flesh. Bean meal is also widely used in the rations of fattening bullocks, and, when finely ground, it forms part of the rations of young calves. It is rich in protein, containing about 25 per cent. of this constituent. Its main function, therefore, is to supplement feeding stuffs poor in protein. Bean meal contains about 3 per cent. of ash, which constitutes a useful source of lime and phosphate for farm animals.

No feeding stuff is viewed habitually by farmer and dairyman alike with greater suspicion than is bean meal. This sinister reputation was gained many years ago as a result of cases of poisoning which followed the use of the Java bean, the ill-effect being traced to the presence of small amounts of a cyanogenetic glucoside. The modern Fertilizers and Feeding Stuffs Act (*q.v.*), however, defines bean meal in such a way as to exclude the use of the toxic Java bean and also the soya bean. The meal is made chiefly from British field beans, China beans, and Algerian beans, and less frequently from the haricot type of bean. The addition of "bean screenings" and "bean pickings" from haricot beans is permitted. It may be said that, in general, bean meal is a perfectly safe food. (See Beans.)

Peas—Peas are very similar to beans in respect of composition and feeding value. They may be used for the same purposes as beans and in like amounts. Pea meal is defined by the Fertilizers and Feeding Stuffs Act as "the meal obtained by grinding commercially pure peas, as grown." This definition, therefore, does not exclude the use of *Gram* (a leguminous seed which is chiefly imported from India) and of the *Mutter Pea*. The composition of gram meal

FEEDING STUFFS (*Continued*)—

is very similar to that of pea meal, and no great objection can be offered to its inclusion in commercial pea meal. On the other hand, the addition of ground mutter peas should be regarded as an adulteration. Not only are mutter peas worth from £2 to £3 per ton less than genuine peas, but they may also prove to be poisonous if present in more than slight amount, and are frequently imported in a dirty condition. (See Peas.)

Lentils—Lentils contain about 23 per cent. of protein and, as lentil meal, constitute a valuable food for dairy cows. The latter may be given from 2 to 4 lbs. per head daily. The ash of lentils is said to be rich in iron.

Soya Bean—The leguminous seeds so far dealt with contain no more than 1 to 1·5 per cent. of oil. On the other hand, the soya bean, which is a leguminous seed imported mainly from Japan and Manchuria, is exceedingly rich in oil. It contains about 18 per cent. of oil and 33 per cent. of protein. It does not come on to the market as such, but in the form of the residue left after separation of a large proportion of the oil in the oil-crushing mills. Soya bean cake will be dealt with in the section on oil cakes and meals.

Ground Nut (Earth Nut, Monkey Nut, Pea Nut)—The ground nut is the fruit of a leguminous plant which grows in most hot countries, notably on the east and west coasts of Africa. It possesses the peculiar characteristic of maturing underground. It contains about 45 per cent. of oil and 27 per cent. of protein. After crushing out the oil, the residue is marketed under the name of ground-nut cake or earth-nut cake. This feeding stuff is discussed in the section dealing with oil cakes and meals.

(*b*) *The Cereal Grains and their By-Products.*

The cereal grains are employed in animal feeding for the purpose of enriching rations in respect of digestible carbohydrate. They are referred to as carbohydrate concentrates on account of their richness in starch. They comprise the home-grown grains, wheat, oats, barley and rye, and the imported grains, rice and maize. Among the by-products of industrial processes dealing with cereals are to be numbered such well-known feeding stuffs as bran, broad bran, middlings, brewers' grains, malt coombs, maize gluten feed and maize gluten meal.

Oats—The composition of oats is better balanced for feeding than that of any other cereal, and this largely explains its popularity with stock feeders. Oats contain, on an average, about 10·5 per cent. of protein, 4·8 per cent. of oil, 58 per cent. of carbohydrate, 10 per cent. of fibre, and 3 per cent. of ash. The composition and feeding value of oats is affected by variation in the proportion of husk in the grain. (See Oats.) It should be noted that oats are fairly rich in lime and phosphate, and therefore do not share the lime-deficient character common to the other cereals.

Oats may be fed safely and liberally to most classes of stock, though

FEEDING STUFFS (*Continued*)—

it is advisable to store them for a few weeks after harvest if they are to be given to horses. They are a valuable ingredient of the diet of dairy cows, provided they are supplemented with food richer in protein. Frequent use is also made of them in the rations of young animals, such as calves, lambs, and foals.

Wheat—The composition of wheat is variable, but on an average it contains about 12 per cent. of protein, 2 per cent. of oil, 69 per cent. of starch, 1·9 per cent. of fibre, and 1·7 per cent. of ash. Compared with oats, therefore, wheat is much richer in starch and contains rather more protein, but is poorer in oil, ash, and fibre. Its fibre content is so low that it tends to become pasty during mastication, and swallowing is thus rendered difficult, for which reason, it should never form more than a small part of the ration. It is always a popular food for poultry. In years when the sale of wheat is unprofitable, it is frequently ground for pigs or crushed for other animals. (See Wheat.)

Barley—Barley is somewhat similar to wheat in composition, and contains on an average 8·6 per cent. of protein, 1·5 per cent. of oil, 68 per cent. of carbohydrate, 4·5 per cent. of fibre, and 2·6 per cent. of ash. Owing to its higher fibre content, it is more palatable than wheat and does not develop pastiness during mastication. It is one of the most popular foods for pigs, but it should be remembered, in this connection, that barley meal is deficient in protein and ash. For all but the full-grown fattening pig, barley meal must be fed in conjunction with foods supplying liberal amounts of protein and ash. (See Barley.)

Rye—In the British Isles this cereal is only available in limited amounts for farm animals. Its composition is very similar to that of wheat. According to Kellner, it is considered to serve rather for the production of energy than for fattening. It is liable to upset the digestive organs, and in a fresh condition is the most dangerous of all the cereals. It may be given whole, after being cooked, to horses, but not to the extent of more than half of the corn ration. Sheep may be given up to ½ lb. per day. Fattening pigs should have the rye ground, and this should then be given either dry or scalded, as a supplementary food with potatoes, middlings, fish meal, etc. (See Rye.)

Maize—Maize is the most ill-balanced of the cereals commonly used in feeding animals. It is extremely rich in starch, but poor in protein, ash, and fibre. It is fairly rich in oil, this constituent amounting to about 4·5 per cent. To secure the advantage of the well-known fattening properties of this cereal, care should be taken to feed it in conjunction with feeding stuffs rich in protein and ash. (For an account of recent work on the composition and nutritive value of maize, see Foods and Feeding; also Maize..)

Flaked Maize—See Foods and Feeding.

Maize By-Products—In the manufacture of cornflour and glucose from maize, several important by-products arise. Among these may be mentioned the following: *Maize Gluten Feed*—This contains about

FEEDING STUFFS (*Continued*)—

25 per cent. of protein, 3 per cent. of oil, and 55 per cent. of carbohydrates. *Maize Gluten Meal*—This by-product contains 35 per cent. of protein, 5 per cent. of oil, and 45 per cent. of carbohydrate. In both the gluten meal and the gluten feed, the amounts of ash and fibre are very low. Both feeding stuffs are useful for increasing the protein content of the rations of all farm stock. *Maize Germ Meal*—This maize by-product contains only 12 per cent. of protein and is rich in oil, roughly 13·5 per cent. of this constituent being present. It is a very suitable food for dairy cows and fattening sheep and bullocks, but is little used for pigs on account of its high oil content. It has attained wide popularity as a supplementary food for pasturing stock. For this purpose it is compressed into the form of cubes.

Rice—Rice is imported mainly for human consumption. The inferior samples of grain, however, are frequently ground or crushed for feeding to farm animals. Rice after polishing is an even more ill-balanced food than maize. It contains as much as 78 per cent. of carbohydrate and only 7 per cent. of protein. Its oil content is as low as 0·5 per cent., whilst of fibre and ash it contains about 1 and 0·8 per cent. respectively. Good results with rice are only possible when it is fed along with foods rich in protein and ash. (See Rice.)

Rice Meal (Rice Bran)—This is produced by grinding the outer layers of the rice kernel which are separated during the process of rice polishing, together with a proportion of the hulls or husk of the grain. It should not contain more than 12 per cent. of fibre. It is rich in protein and oil, containing 13 and 14 per cent. of these constituents respectively. It is used largely for fattening cattle, and as a binding material in the manufacture of mixed feeding cakes. Its richness in oil precludes its use for pigs. It should also be fed only sparingly to dairy cows owing to its softening effect on the butter fat. It should also be remembered that the oil in rice meal is liable to turn rancid during storage of the food, and rice meal, therefore, should be fed in the fresh condition.

Millet—This is a popular grain for poultry. It contains 61 per cent. of carbohydrate, 11 per cent. of protein, 4 per cent. of fat, 8 per cent. of fibre, and 4 per cent. of ash.

Dari—This grain is mainly used in poultry feeding. It contains 69 per cent. of carbohydrate, 10 per cent. of protein, 4 per cent. of oil, and only small amounts of fibre and ash.

Buckwheat—This grain is imported or home-grown mainly for feeding to poultry, and is reputed to produce a very white flesh. Less frequently it is used for dairy cows, but excessive feeding tends to give a tallowy butter. Its composition is somewhat similar to that of oats, except that it contains rather more fibre and rather less oil. Its feeding value, therefore, is not quite as high as that of oats.

Miller's Offals—This class includes the various products separated from the wheat kernel during milling, the main fractions being bran, pollards, coarse middlings and fine middlings. For an account of

FEEDING STUFFS (*Continued*)—

recent work on the grading, composition, and feeding value of wheaten offals, the reader should consult Foods and Feeding. Reference should be made here to the two kinds of bran which find their way on to the market—namely, broad bran and ordinary bran. Broad bran is obtained by sifting out the largest flakes from straight-run bran, the residue constituting medium bran or fine bran. From the broad bran practically all the dusty material has been removed. Many feeders prefer the larger flakes, and consequently the miller can command a better price for the broad bran. From the standpoints of composition and feeding value, however, there is little to distinguish broad bran from ordinary bran.

Brewers' Grains—These are a by-product of the brewery, and consist of the residue of barley and other ingredients of the mash left when the wort is separated after mashing. The bulk of the starch of the barley grain has been removed. In the fresh condition, brewers' grains contain about 75 per cent. of water. They are very perishable, and their use is therefore limited to farms in the vicinity of the brewery. They are mainly used for feeding to dairy cows. Dried brewers' grains result from the drying down of the wet grains in special appliances. In this form they contain about 18 per cent. of protein, 46 per cent. of carbohydrate, and 15 per cent. of fibre. Their feeding value is comparable with that of bran, though they do not possess the laxative properties of that feeding stuff. They are a safe food for cattle, dairy cows, and sheep, but are unsuitable for pigs.

Distillers' Grains—These resemble brewers' grains in composition, but are usually slightly richer in protein. They lack the palatability of brewers' grains and are frequently slightly acid.

Malt Coombs—These consist of the dried rootlets separated from malt after curing. They form a bulky, palatable food which contains about 24 per cent. of crude protein, 49 per cent. of carbohydrate, and 10 per cent. of fibre. About one-third of the crude protein is in the form of simple nitrogenous material of the asparagine type. They are a favourite food for dairy cows and lambs.

(*c*) *Oil Cakes and Meals.*

Oil cakes and meals are the residues left after removal of the oil from oily seeds and fruits. There are two main methods of removing the oil: (1) By pressure; this results in the production of oil cakes containing from 5 to 10 per cent. of oil. (2) By extraction with solvents such as petrol and benzene; this process leaves a meal which contains, on an average, not more than 1 to 2 per cent. of oil.

Coconut Cake—The dried kernel of the coconut is known as copra. From this is expressed or extracted the coconut oil of commerce. The coconut cake produced by the pressure process has a brownish-grey colour and a smell reminiscent of copra. It contains, on an average, 21 per cent. of protein, 10 per cent. of oil, and 11 per cent. of fibre. Though not so popular in this country as in America and on the Con-

FEEDING STUFFS (*Continued*)—

tinent, coconut cake has been found to be a valuable protein concentrate for dairy cows and fattening cattle. Owing to its capacity for absorbing moisture, it does not store as safely as the other oil cakes. It should be kept in a very dry place.

Cotton Cake—The residue which is left after expressing the oil from cotton seed is known as **Undecorticated Cotton Cake.** It has a greenish-yellow colour and the dark-coloured husks of the cotton seed are very conspicuous. It contains about 22 per cent. of protein, 5 per cent. of oil, and 22 per cent. of fibre. It will be noted, therefore, that the fibre content of undecorticated cotton cake approaches that of good hay, for that reason its nutritive value is not so high as that of the other oil cakes. It has, however, a special use as a supplementary food for animals on rich pasture, in that its astringent properties act as a preventive against "scouring." Two kinds of undecorticated cotton cake come on to the market—namely, Egyptian and Bombay. The Bombay cake can be distinguished by the presence of cotton fibres on its broken edges. The two kinds, however, are approximately equal in feeding value.

When the cotton seeds are decorticated, *i.e.*, freed from husk, before being crushed, the residue is known as **Decorticated Cotton Cake.** The protein content and nutritive value of the decorticated cake are much higher than those of the undecorticated. It contains about 40 per cent. of protein, 10 per cent. of oil, and only 7·6 per cent. of fibre. It is bright yellow in colour and rather hard in texture. It is a very popular food for cattle, sheep, and dairy cows. It is frequently ground to a meal and sold under the names of decorticated cotton-seed meal or "yellow meal."

Ground-Nut Cake (Earth-Nut Cake)—This reaches the market in the undecorticated, semi-decorticated, and decorticated forms. Decorticated ground-nut cake contains about 47 per cent. of protein, 7 per cent. of oil, and 6 per cent. of fibre. It compares quite favourably in feeding value with the other oil cakes, and has recently been recommended for feeding, in admixture with suitable minerals, as a cheap substitute for fish meal in pig feeding. As its composition indicates, comparatively small amounts of decorticated earth-nut cake will satisfy the requirements of farm animals for protein. Undecorticated earth-nut cake contains about 30 per cent. of protein and 23 per cent. of fibre. Its feeding value is rather higher than that of undecorticated cotton cake, though it does not possess the valuable astringent properties of the cotton-seed by-product.

Linseed Cake—Linseed cake is one of the safest and most popular of the feeding stuffs. It is a favourite food for nearly all farm stock, including fattening cattle, dairy cows, lambs, and calves. It is specially liked because of the "bloom" it produces in fattening bullocks. It has a gentle laxative action, and the mucilage which it contains exerts a soothing effect on the bowels of animals. A pure sample of linseed cake should show the presence of thin red husks embedded in the yellowish-grey material of the seed. It should be free from starch,

FEEDING STUFFS (*Continued*)—

sand, and weed seeds, and should possess the characteristic smell of linseed when steeped in hot water. An average sample contains about 30 per cent. of protein, 10 per cent. of oil, 35 per cent. of carbohydrate, 9 per cent. of fibre, and 5 per cent. of ash. Linseed cake is sometimes ground and sold under the name of linseed cake meal. This should not be confused with linseed meal, which is made by grinding the whole seed, and contains approximately 36 per cent. of oil. Extracted linseed cake meal, produced from linseed by the extraction of the oil with solvents, contains 36 per cent. of protein and only about 3 per cent. of oil.

Palm-Kernel Cake—This is a greyish-white cake marked with black specks of husk. It contains about 18 per cent. of protein, 7 per cent. of oil, and 13 per cent. of fibre. It is frequently used in the rations of dairy cows and cattle. It has also been found to give satisfactory results with pigs when fed in conjunction with small amounts of dried blood. It was first brought to the notice of feeders in this country during the Great War, but has never become really popular on account of its lack of palatability and the difficulty animals have in becoming accustomed to it. When the oil of palm kernels is removed by means of solvents, the residue is known as extracted palm-kernel meal. This contains only about 2 per cent. of oil.

Rape Cake—Rape cake, made from rape or colza seed, is very little used in this country. It cannot be regarded as an entirely safe food for stock, and, in addition, it has a rather unpleasant bitter flavour. It may be used in moderation for fattening cattle, dairy cows, and sheep, but should never be fed to young stock. It contains, on an average, about 36 per cent. of protein, 9·5 per cent. of oil, 8 per cent. of fibre, and 12 per cent. of ash. Low-grade rape cake is frequently employed in manuring as a source of organic nitrogen.

Sesame Cake—Sesame cake is exceedingly rich in protein, containing as much as 44 per cent. of this constituent. On this account, it should be used sparingly in the rations of animals. It is not, however, much used in Great Britain, but has attained a fair degree of popularity in France and Germany, where it is regarded as having a stimulating influence on the milk flow.

Soya-Bean Cake—This is a hard, light-coloured cake containing about 42 per cent. of protein, 7 per cent. of oil, and 5 per cent. of fibre. On account of its richness in protein and its laxative action, it is advisable to include only small allowances of soya-bean cake in the rations of farm animals. In the feeding of a fattening beast, for instance, it is not desirable to supply the necessary digestible protein entirely in the form of soya-bean cake, but to give a mixture of this and another oil cake of lower protein content. For this reason, the compound cake known as **Soycot Cake,** made by crushing a mixture of soya beans and cotton seeds, has acquired considerable favour in recent years, since it is found that the astringent qualities of the cotton seed counteract to a large extent the laxative nature of the soya beans.

FEEDING STUFFS (*Continued*)—

Sunflower Cake—This cake is made from the seeds of the sunflower. In the undecorticated form it contains 19 per cent. of protein and as much as 30 per cent. of fibre. The decorticated cake, however, contains only 12 per cent. of fibre, whereas the protein content is as high as 37 per cent. Sunflower cake is not much used as such in this country, but is frequently incorporated in compound foods.

MISCELLANEOUS FEEDING STUFFS—The dietary of farm animals in the British Isles has undergone considerable extension during recent years as a result of the introduction of sundry feeding stuffs which arise as by-products of industries concerned with the preparation of foods for human consumption. The most important of these by-products are dealt with in this section.

White Fish Meal—This feeding stuff is defined as "a product (containing not more than 6 per cent. of oil and not more than 4 per cent. of salt) obtained by drying and grinding or otherwise treating waste of white fish, and to which no other matter has been added." It contains more than 50 per cent. of protein and about 20 per cent. of mineral matter, the latter being mainly composed of phosphate of lime. It is to these features that the special value of fish meal as a food for growing animals and dairy cows is to be attributed. It is doubtful whether fish meal is to be regarded as a rich source of vitamin A. In view of its high protein content, it should be fed only in small quantities to farm animals. The ration of the pig should not contain more than 4 to 8 ozs. per day, according to size. It has been definitely ascertained that white fish meal, if made entirely from the heads, bones, and flesh of white fish, produces no taint in bacon, pork, milk, eggs, or chicken flesh. With swine, all risk of tainting disappears if the use of fish meal is discontinued during the last month of fattening. Cheap and efficient substitutes for fish meal in the feeding of pigs are: (1) A mixture of decorticated earth-nut meal and a little steamed bone flour; (2) a mixture of palm-kernel cake and a small allowance of dried blood; (3) extracted soya-bean meal plus minerals.

Herring Fish Meal—A second grade of fish meal is made from the refuse of herrings, mackerel, and other oily fish. Such fish meal, containing from 10 to 20 per cent. of oil, is not desirable for feeding purposes on account of the risk of taint. The so-called herring fish meal, if made from salted herring, often contains large amounts of common salt, which may affect the health of the animals adversely.

Dried Blood—This by-product of the slaughter-house comes into the market as a dark brown powder containing about 80 per cent. of protein, the rest of the material consisting mostly of moisture. It is an excellent supplement to grain and grain offals in the rations of young swine, when fed at the rate of 1 to 2 ozs. per day. Quantities larger than this should not be fed owing to its extremely high protein content.

Meat Meal—This is produced by drying and grinding the refuse, other than bones, in factories where meat is canned, or where meat

FEEDING STUFFS (*Continued*)—

extract is made. It contains 70 per cent. of protein (which being flesh protein is very efficient in producing growth in young animals), and 10 to 15 per cent. of fat. A good meat meal containing not too much fat is probably the best substitute which can be found for fish meal. For this purpose, however, it is usually necessary to bring up the percentage of mineral matter by the addition of steamed bone flour, or, alternatively, by including whey in the ration.

Carcass Meal—This is obtained when the bones are ground up with the refuse meat. It contains 50 per cent. of protein, 15 per cent. of fat, and 20 per cent. of mineral matter. The latter, as with fish meal, consists mainly of phosphate of lime.

Dried Yeast.—This feeding stuff, which results from the drying of waste yeast from breweries, contains about 50 per cent. of protein, practically no fibre and oil, and roughly 10 per cent. of mineral matter. It is particularly rich in vitamin B. On account of its richness in protein, it should be fed only in small quantities, and in the daily rations of pigs not more than 4 to 8 ozs. should be included. Sheep digest and assimilate nearly 90 per cent. of the crude protein in dried yeast. A consideration of the nature of the crude protein, however, leads to the belief that this constituent as found in dried yeast cannot be as efficient for growth purposes as the protein of fish meal or meat meal. During the Great War, German scientists manufactured this protein concentrate on a large scale by allowing a special variety of yeast to grow in solutions containing beet molasses and sulphate of ammonia, the latter having been made synthetically from the nitrogen of the air. By these means, atmospheric nitrogen was indirectly transformed into a valuable nitrogenous food, which in turn underwent conversion into milk and flesh protein in the bodies of farm animals.

Dried Potatoes and Potato Flakes.—Attempts are being made at the present time in this country to conserve part of the potato crop by a process of artificial drying, a method of treatment which has been practised for some years on the Continent. In this way, it is possible to utilize profitably the small unsaleable tubers, and, further, to carry over from one season to another any surplus of potatoes which may be secured in a good season. German feeding trials have shown that dried potatoes, particularly in the flaked form, are a valuable addition to the carbohydrate foods available for feeding swine.

Manioc Meal (Tapioca Flour)—Large quantities of this carbohydrate-rich by-product of the cassava root are now finding their way on to the home market. This feeding stuff is to be regarded essentially as a source of digestible carbohydrate, and it should only be fed to pigs in conjunction with protein and mineral supplements. It contains about 81 per cent. of carbohydrate, only 3 per cent. of protein, 0·6 per cent. of oil, 1·7 per cent. of fibre, and 1·9 per cent. of ash. It has been shown to be suitable for replacing maize meal or barley meal up to at least 25 per cent. of the total ration.

Molasses—This is the syrup left after the crystallization of sugar from beet juice. Its water content is variable, the extreme

FEEDING STUFFS (*Continued*)—

COMPOSITION AND NUTRITIVE VALUE OF FEEDING STUFFS.

(NOTE.—In the compilation of these data, the following treatises, in addition to sundry publications of original research, have been consulted: "Rations for Live Stock"—T. B. Wood. (*Min. Agric.*, Misc. Pub. No. 32, 1930, obtainable from the Secretary, Ministry of Agriculture and Fisheries, price 6d.) "Animal Nutrition and Veterinary Hygiene"—R. G. Linton. "Die Ernährung der landwirtschaftlichen Nutztiere"—O. Kellner. The compiler is particularly indebted to the first of these publications.

Feeding Stuff.	*Chemical Composition per Cent.*						*Digestible Composition per Cent.*				*Nutritive Value.*	
	Dry Matter.	*Crude Protein.*	*Ether Extract.*	*Nitrogen-Free Extractives.*	*Crude Fibre.*	*Ash.*	*Crude Protein.*	*Ether Extract.*	*Nitrogen-Free Extractives.*	*Crude Fibre.*	*Starch Equivalent per 100 Lbs.*	*Nutritive Ratio.*
1. COARSE FODDERS.												
Barley straw	86·0	3·3	1·8	42·4	33·9	4·6	0·8	0·6	22·5	18·3	23	1 : 52
Bean straw (including pods)	86·0	4·5	0·8	33·0	43·1	4·6	2·2	0·5	22·0	18·7	23	1 : 19
Oat straw (spring)	86·0	2·9	1·9	42·4	33·9	4·9	1·0	0·6	19·4	18·3	20	1 : 39
Oat straw (winter) ..	86·0	1·9	1·5	43·1	34·6	4·9	0·6	0·5	19·8	19·7	21	1 : 67
Wheat straw (spring) ..	86·0	2·9	1·3	39·8	35·9	6·1	0·1	0·4	14·7	18·0	13	1 : 336
Wheat straw (winter) ..	86·0	2·1	1·3	40·7	36·6	5·3	0·1	0·4	15·0	18·3	13	1 : 342
Wheat cavings	86·0	3·8	1·8	39·8	32·0	8·6	—	—	—	—	—	—
Wheat chaff (glumes) ..	86·0	3·7	1·2	42·6	27·7	10·8	—	—	—	—	—	—
Meadow hay (poor) ..	85·7	7·5	1·5	38·2	33·5	5·0	3·4	0·5	19·3	15·6	22	1 : 11
Meadow hay (good) ..	85·7	9·7	2·5	41·0	26·3	6·2	5·4	1·0	25·7	15·0	37	1 : 8
Meadow hay (very good) ..	84·0	13·5	3·0	40·5	19·3	7·7	9·2	1·5	30·1	12·7	48	1 : 5
Seeds hay (rye grass and clover)	86·0	12·0	2·8	37·4	27·5	6·3	6·2	1·2	22·0	13·2	29	1 : 6
Red clover hay (good) ..	83·5	13·5	2·9	37·1	24·0	6·0	8·5	1·7	26·0	11·3	38	1 : 5
2. GREEN FODDERS.												
Pasture grass (intensive grazing)	20·0	5·3	1·1	8·9	2·6	2·1	4·5	0·7	7·8	2·1	14·6	1 : 2·5
Pasture grass (extensive grazing)	20·0	3·5	0·8	9·7	4·0	2·0	2·5	0·4	7·3	2·6	11·2	1 : 4
Lucerne	24·0	4·5	0·8	9·6	6·8	2·3	3·2	0·4	6·3	2·9	9·1	1 : 3
Sainfoin (in flower) ..	20·0	3·5	0·6	7·8	6·9	1·2	2·3	0·3	4·8	3·2	7·6	1 : 4
Crimson clover	18·5	2·8	0·7	6·9	6·2	1·9	2·1	0·5	5·2	3·5	8·9	1 : 5
Red clover	19·0	3·4	0·7	8·1	5·2	1·6	2·5	0·5	6·3	3·0	10·2	1 : 4
Tares (vetches)	17·5	3·2	0·5	7·2	5·1	1·5	2·2	0·3	4·9	2·3	7·5	1 : 4
Green maize	19·4	1·7	0·5	10·4	5·6	1·2	1·0	0·3	6·7	3·1	9·1	1 : 10
Oat and tare silage (green fruity)	27·3	3·4	1·2	12·5	8·0	2·2	2·2	0·9	8·7	4·6	12·8	1 : 7
Oat and tare silage (acid brown)	34·6	5·6	1·5	12·9	11·4	3·2	3·8	1·2	6·4	5·5	13·0	1 : 4
Rape	14·8	3·0	0·8	6·0	4·0	1·0	2·0	0·5	4·0	2·0	7·0	1 : 4
Mustard	14·4	3·0	0·4	7·0	3·0	1·0	2·0	0·2	5·0	1·5	7·2	1 : 4
Marrow-stem kale ..	14·3	2·4	0·2	6·4	3·8	1·5	1·8	0·1	5·2	2·8	8·9	1 : 5
Cabbages (drumhead) ..	11·0	1·5	0·4	5·9	2·0	1·2	1·1	0·2	4·6	1·4	6·6	1 : 6
Sugar-beet tops	16·2	2·0	0·5	8·7	1·6	3·4	1·4	0·3	7·2	1·1	8·6	1 : 6

FEEDING STUFFS (*Continued*)—

COMPOSITION AND NUTRITIVE VALUE OF FEEDING STUFFS (*Continued*).

Feeding Stuff.	*Chemical Composition per Cent.*						*Digestible Composition per Cent.*				*Nutritive Value.*	
	Dry Matter.	*Crude Protein.*	*Ether Extract.*	*Nitrogen-Free Extractives.*	*Crude Fibre.*	*Ash.*	*Crude Protein.*	*Ether Extract.*	*Nitrogen-Free Extractives.*	*Crude Fibre.*	*Starch Equivalent per 100 Lbs.*	*Nutritive Ratio.*
3. SUCCULENT FOODS.												
Sugar-beet	23·4	1·1	0·1	20·4	1·1	0·7	0·8	—	19·3	0·4	15·0	1 : 25
Mangolds (white globe) ..	10·7	1·0	0·1	8·2	0·7	0·7	0·7	—	7·5	0·8	5·5	1 : 11
Mangolds (long red) ..	13·1	1·0	0·1	10·3	0·8	0·9	0·7	—	9·5	0·3	6·8	1 : 14
Turnips	8·5	1·0	0·2	5·7	0·9	0·7	0·6	—	5·2	0·3	4·4	1 : 9
Swedes	11·5	1·3	0·2	8·1	1·2	0·7	1·1	—	7·5	0·8	7·3	1 : 7
Carrots	13·0	1·2	0·2	9·3	1·4	0·9	0·8	0·1	8·9	0·7	8·8	1 : 12
Parsnips	15·0	1·3	0·3	11·3	1·2	0·9	1·0	0·1	10·9	0·7	10·6	1 : 12
Kohl rabi	12·7	2·0	0·1	8·2	1·4	1·0	0·7	—	7·4	0·6	8·3	1 : 11
Potatoes	23·8	2·1	0·1	19·7	0·9	1·0	1·1	—	17·7	—	17·8	1 : 16
Artichoke (Jerusalem) ..	20·4	1·5	0·2	16·9	0·7	1·1	1·0	—	15·8	0·2	16·4	1 : 16
4. LEGUMINOUS GRAINS.												
Beans	85·7	25·4	1·5	48·5	7·1	3·2	20·1	1·2	44·1	4·1	65·8	1 : 2
Peas	86·0	22·5	1·6	53·7	5·4	2·8	19·4	1·0	49·9	2·5	69·0	1 : 3
Gram	89·0	23·4	1·1	54·3	5·1	5·1	15·5	0·7	50·5	2·9	71·0	1 : 3
Lentils	86·0	25·5	1·9	52·2	3·4	3·0	21·9	1·2	48·5	1·8	70·0	1 : 3
5. CEREAL GRAINS AND BY-PRODUCTS.												
Barley	85·1	8·6	1·5	67·9	4·5	2·6	6·5	1·2	62·2	2·5	71·0	1 : 10
Dari	88·9	9·6	3·8	71·2	1·9	2·4	7·7	3·0	60·5	1·0	74·1	1 : 9
Maize	87·0	9·9	4·4	69·2	2·2	1·3	7·9	2·7	63·7	0·8	77·6	1 : 9
Millet	87·5	10·6	3·9	61·1	8·1	3·8	8·0	3·1	45·8	2·7	58·9	1 : 7
Oats	86·7	10·3	4·8	58·2	10·3	3·1	8·0	4·0	44·8	2·6	59·5	1 : 7
Buckwheat	85·9	11·3	2·6	54·8	14·4	2·8	8·5	1·9	42·3	3·5	53·4	1 : 6
Rice (polished)	87·4	6·7	0·4	78·0	1·5	0·8	5·8	0·2	75·8	0·7	82·1	1 : 13
Rye	86·6	11·5	1·7	69·5	1·9	2·0	9·6	1·1	63·9	1·0	71·6	1 : 7
Wheat	86·6	12·1	1·9	69·0	1·9	1·7	10·2	1·2	63·5	0·9	71·6	1 : 7
Flaked maize	89·0	9·8	4·3	72·5	1·5	0·9	9·4	2·0	70·4	0·5	84·0	1 : 8·5
Maize gluten feed	89·6	23·5	3·4	56·7	3·5	2·5	20·0	2·7	49·3	2·5	75·6	1 : 3
Maize gluten meal ..	90·9	35·5	4·7	47·5	2·1	1·1	30·6	4·4	42·6	—	81·5	1 : 2
Maize germ meal	88·0	10·0	11·0	59·0	7·0	1·0	9·0	10·0	48·0	2·0	79·0	1 : 8
Bran	87·0	15·1	3·9	52·8	9·5	5·7	10·9	2·6	37·4	2·2	42·0	1 : 4
Coarse middlings	86·0	15·8	4·9	56·8	4·9	3·6	11·5	4·2	48·2	—	58·0	1 : 5
Fine middlings	86·7	17·0	4·2	60·8	2·3	2·4	12·6	3·7	51·1	—	69·0	1 : 5
Brewers' grains (dry) ..	89·7	18·3	6·4	45·9	15·2	3·9	13·0	5·6	27·6	7·3	48·3	1 : 4
Distillers' grains (dry) ..	92·0	27·7	11·6	40·8	10·1	1·8	19·6	10·2	25·3	4·8	57·2	1 : 3
Malt coombs	90·0	24·4	2·0	42·4	14·0	7·2	19·9	1·5	30·9	12·7	43·4	1 : 3
6. OIL CAKES AND MEALS.												
Coconut cake	88·6	20·7	9·9	41·4	11·2	5·4	16·2	9·6	34·3	7·1	79·1	1 : 4
Cotton cake (undecort.) ..	87·9	23·0	5·5	32·4	21·2	5·8	17·6	5·1	17·5	4·5	41·8	1 : 2
Cotton cake (decort.) ..	90·2	40·2	9·9	25·9	7·6	6·6	34·6	9·3	17·3	2·1	70·7	1 : 1

FEEDING STUFFS (*Continued*)—

COMPOSITION AND NUTRITIVE VALUE OF FEEDING STUFFS (*Continued*).

Feeding Stuff.	*Chemical Composition per Cent.*						*Digestible Composition per Cent.*				*Nutritive Value.*	
	Dry Matter.	*Crude Protein.*	*Ether Extract.*	*Nitrogen-Free Extractives.*	*Crude Fibre.*	*Ash.*	*Crude Protein.*	*Ether Extract.*	*Nitrogen-Free Extractives.*	*Crude Fibre.*	*Starch Equivalent per 100 Lbs.*	*Nutritive Ratio.*
6. OIL CAKES AND MEALS (*Continued*).												
Ground-nut cake (undecort.)	89·7	30·2	9·1	21·8	22·9	5·7	27·7	8·2	18·4	2·6	56·8	1 : 1
Ground-nut cake (decort.)	89·7	46·8	7·5	23·2	6·4	5·8	42·0	6·8	19·7	0·5	73·0	1 : 1
Linseed cake	88·8	29·5	9·5	35·5	9·1	5·2	25·3	8·7	28·5	4·5	74·0	1 : 2
Palm-kernel cake	88·3	17·4	9·0	44·6	13·8	3·5	15·4	8·8	35·1	2·8	73·6	1 : 4
Rape cake	91·4	35·5	9·6	25·6	8·3	12·4	29·4	7·6	20·5	0·7	59·5	1 : 1
Sesame cake	90·7	44·5	11·9	20·9	4·5	8·9	40·0	10·7	11·7	1·4	73·0	1 : 1
Soya-bean cake	85·5	42·4	7·0	25·8	5·0	5·3	38·2	6·4	20·0	3·6	69·1	1 : 1
Sunflower cake (decort.) ..	90·4	37·4	13·8	20·4	12·1	6·7	33·6	12·2	14·6	3·6	72·5	1 : 1
7. MISCELLANEOUS FEEDING STUFFS.												
White fish meal	87·0	55·6	4·4	2·1	—	24·9	50·0	4·2	—	—	52·6	—
Dried blood	86·0	81·0	0·8	1·5	—	2·7	72·7	0·8	—	—	62·9	—
Meat meal	89·2	72·2	13·2	—	—	3·8	67·2	12·5	—	—	91·0	—
Carcass meal	93·0	50·3	17·0	1·0	2·7	22·0	39·2	16·2	—	—	61·7	1 : 1
Dried yeast	92·0	49·0	3·0	30·0	—	10·0	43·0	1·0	25·0	—	66·0	1 : 1
Manioc meal (tapioca flour)	87·9	3·1	0·6	80·6	1·7	1·9	—	—	—	—	—	—
Potato pulp (dry)	86·0	3·4	0·1	68·2	8·8	5·5	—	—	56·6	2·1	55·8	—
Dried sugar-beet pulp ..	90·0	8·9	0·6	59·1	18·3	3·1	5·3	—	54·0	16·3	65·5	1 : 13
Molasses sugar-beet pulp ..	90·0	10·8	0·4	58·2	15·1	5·5	6·3	—	53·0	13·5	63·0	1 : 11
Beet molasses	74·7	3·5	—	66·0	—	5·2	1·2	—	59·2	—	51·6	—
Separated milk	9·4	3·5	0·1	5·0	—	0·8	3·3	0·1	5·0	—	8·3	1 : 2
Whey	6·6	0·7	0·2	5·0	—	0·7	0·6	0·2	5·0	—	6·1	1 : 9

values of 15 and 32 per cent. having been noted. It contains about 66 per cent. of carbohydrate, which consists mainly of sucrose (cane-sugar) together with about 3 per cent. of a trisaccharide known as raffinose. Its crude protein content amounts to about 4 per cent., but this consists largely of useless nitrogenous material like betaine. Only about 0·5 per cent. of true protein is present. Beet molasses also contains about 5 per cent. of ash, this fraction being very rich in potash salts, but almost free from phosphates. Only an insignificant amount of lime salts occurs in the ash. If fed too liberally, molasses may cause "scouring" owing to its high content of alkaline salts. It is frequently employed to improve the palatability of chaff and of palm-kernel cake. In many beet-sugar factories it is mixed with

FEEDING STUFFS (*Continued*)—

wet sugar-beet pulp, dried, and sold under the name of molasses sugar-beet pulp. This feeding stuff may contain as much as 20 per cent. of molasses. Molasses is also frequently taken up in absorbent materials, such as peat and sugar-cane refuse, in the manufacture of the so-called molasses feeds. Care should be exercised in the purchase of such mixed foods, as the absorbent basis is liable to be of negligible feeding value.

Separated Milk—This by-product of the dairy industry contains about 10 per cent. of dry matter, mainly composed of protein, milk sugar, and ash. It is frequently used in feeding calves and young pigs. Where desirable, as with calves, the fat deficiency can be made up by the addition of crushed linseed or cod-liver oil.

Whey—Compared with whole milk, whey is deficient in fat and protein. It contains only about 7 per cent. of dry matter, and so has an inferior feeding value compared with separated milk. To bring a gallon of whey up to the value of a gallon of whole milk, it is necessary to add $\frac{1}{3}$ lb. of oil and $\frac{1}{4}$ lb. of protein. The following mixtures have been found to give good results in the supplementing of whey for calves: (1) Linseed meal, 3 parts; bean meal, 3 parts; fish meal, 1 part. (2) Linseed cake meal, 4 parts; bean meal, 5 parts. The meal mixtures should be used at the rate of 1 lb. to a gallon of whey. From what has been written, it is clear that whey, by itself, is to be regarded as a carbohydrate-rich food.

H. E. W.

FEEDING STUFFS, THE MANURIAL VALUE OF—The manurial value of feeding stuffs has been mainly studied in connection with the general problem of compensation to outgoing tenants for unexhausted improvements, and the principal developments in our knowledge of the subject have been largely associated with the replacement of one of the Agricultural Holdings Acts by its successor. Since the present position is very definitely the result of an historical development, and as, moreover, many of the earlier views on this subject still persist in practice, it is proposed to make this article an outline of the general history of the subject. (See Improvements and other Rights, Compensation for, Particularly Relating to Agricultural Tenants.)

Early Misconceptions—It is difficult to say precisely when the practical importance of the manurial value of feeding stuffs was first generally realized, but considerable emphasis was placed upon it by a number of writers before the middle of the last century. It is apparent from these writings that local customs were then springing up in assessing the compensation to be paid to outgoing tenants for the unexhausted manurial value of recently consumed feeding stuffs. These local customs varied considerably, but, for the most part, they assessed the relative manurial value of a feeding stuff on the basis of its price. Moreover, it would appear that this was done with more consistency than is commonly recognized by modern writers, since there was an impression at that time that the concentrated feeding

FEEDING STUFFS, THE MANURIAL VALUE OF (*Continued*)—
stuffs were bought for the making of manure rather than the nutrition of the animal. G. M. Williams, for example, writing to the *Journal of the Royal Agricultural Society* in 1845, says of the feeding of oil cake: "You are aware that this has a most important effect in improving the quality of the manure, though there is seldom much profit to be made from it on the stock itself." Founded on that belief, the custom arose of assessing the enhanced value of manure due to the consumption of concentrated foods as a certain fraction of the cost of the food.

The First Scientific Treatment of the Subject—It was about 1860 that Lawes pointed out that the feeding value, and not the manurial value, of these feeding stuffs was the utility factor determining their price, and that the assessment of their manurial value on the basis of their price was unjustified. In 1870, Lawes read a paper on the subject to the Farmers' Club, which led to a further paper by Lawes and Gilbert in 1875, at the time that the Agricultural Holdings Act was first giving some legal recognition to the principle of compensating tenant farmers who left their farms before securing the benefits of the manurial value of recently consumed feeding stuffs. Lawes and Gilbert published tables giving the estimated manurial value of 1 ton of various feeding stuffs. These papers, and their assessments of manurial values of feeding stuffs, aroused much interest and discussion, and led to the Royal Agricultural Society holding an inquiry, which in turn led to the first steps being taken to test by field experiments the views expressed by Lawes and Gilbert. The Duke of Bedford placed the now famous farm at Woburn at the Society's disposal for such tests to be made.

The Agricultural Holdings Act of 1883 revived further interest in this matter, and a further paper by Lawes and Gilbert appeared in 1885. While the views put forward in this paper have since been modified several times, the paper remains of outstanding importance as affording the basis of all subsequent developments. Tables previously published, showing the percentage of nitrogen, phosphoric acid, and potash in various feeding stuffs were brought up to date in this paper. Thereafter, the writers described experiments for determining by the analyses of carcasses the amounts of these manurial constituents of the feeding stuff which are retained by oxen or sheep during fattening. The difference was presumed to be excreted in the manure, and by considering the prices of common fertilizers the money value of the nitrogen, phosphoric acid, and potash passing into the manure was arrived at. This was described as "the total original manurial value per ton of food consumed." Consideration was next given to the loss of manurial value during the making and storing of the manure, and also to the period of time over which manure would leave an effect after application to the soil. The conclusions reached were that one-half of the total manurial value must be deducted to arrive at the actual manurial value at the time of application to the land. It was further assumed that the effect of a feeding stuff upon the manure would have some value over a period of eight

FEEDING STUFFS, THE MANURIAL VALUE OF (*Continued*)—

years, and that its value in any one of these eight was two-thirds of its value in the preceding year. Hay and straw were dealt with somewhat differently.

The tables put forward by Lawes and Gilbert, and the revised tables which have subsequently appeared were never intended by the authors to afford anything more than a general guide to the valuation of unexhausted manurial effects; in its detail each case must manifestly be dealt with separately.

In 1897 and 1898 Lawes and Gilbert brought their tables up to date by reassessing the manurial value on the basis of fertilizer prices then current.

The tables of Lawes and Gilbert do not appear to have had much influence upon the valuation practice in the years immediately following their publication, but in the long run they have had far-reaching effects, since the subsequent and simpler tables, now generally recognized, are modifications of them.

Reconsiderations, 1902—Further interest in the manurial value of feeding stuffs was stimulated by the Agricultural Holdings Act of 1900, and in 1902 Voelcker and Hall published a paper which is essentially a reconsideration of the Lawes and Gilbert tables—a reconsideration made in the light of subsequently acquired knowledge and also in view of the need for simplification. They reviewed the work carried out at Woburn and at various Continental stations on the losses which take place during the making and storage of manure. In the Woburn experiments, where every precaution is taken to avoid loss, the manure being kept compact in pits from which no drainage of liquid can take place, the loss of nitrogen during making is between 15 and 20 per cent. There is a further loss of about the same amount during storage, making a total loss of 30 to 40 per cent. under the best possible conditions. (See Farmyard Manure.) Experiments both in Germany and in France were quoted and shown to give similar indications regarding the loss of nitrogen. Having regard to these facts and to the fact that some nitrogen is retained by the animal, the authors recommended that one-half the nitrogen in the feeding stuff should be credited to the manure when the manure is first "made."

Voelcker and Hall pointed out that the phosphoric acid in the manure is mostly insoluble, and no loss of the original amount in the feeding stuff is likely to be incurred except that retained by the animal. This varies very much with different feeding stuffs and animals, but on the average a deduction of 25 per cent. was considered reasonable. They also recommended that the whole of the potash in the feeding stuff be credited to the manure, since the amount retained by the animal is very small and the only source of loss is the drainage of urine.

Passing next to the period of the duration of manurial effects, Voelcker and Hall were able to consider much more experimental evidence than was available to Lawes and Gilbert, and they reviewed the relevant experiments carried out at Rothamsted and Woburn.

FEEDING STUFFS, THE MANURIAL VALUE OF (*Continued*)—

The consideration of these experimental results for practical purposes is somewhat complicated. There are a number of experiments which go to show that the residual effect of farmyard manure, and therefore of the manurial value of feeding stuffs, is appreciable over a long period of time. In the Rothamsted continuous barley experiments, for instance, the application of farmyard manure in early years was still doubling the yield of barley thirty years after its application ceased. In the potato experiments the effect of six years of the application of farmyard manure is visible twenty years later. On the hay plots the effect of farmyard manure is quite marked thirty-five years after its application. But the rotation experiments are of more practical value in this connection. Here it is found that the manuring of roots has a marked effect upon the succeeding barley crop, but no appreciable effect on a wheat crop in the fourth year. The Woburn experiments on the whole confirm this. While therefore the manurial value of feeding stuffs has an effect upon the " condition " of the soil which persists for many years, from the practical point of view it still remains necessary to make applications once in each rotation, and Voelcker and Hall consequently recommended that the manurial value of the feeding stuffs should be considered to last for a period of four years and not eight as suggested by Lawes and Gilbert, and that the value should be considered to be reduced by 50 per cent. each year. They accordingly published a revised table in which figures were given for assessing the original manure with the value of half the nitrogen, three-quarters of the phosphoric acid, and the whole of the potash in the feeding stuffs, and assumed that the total value was diminished by half each year after application.

The Central Chamber of Agriculture, which set up a Committee to consider this matter about the time of the passing of the Agricultural Holdings Act, 1900, adopted Voelcker and Hall's tables, except in so far as they altered the period for allowing compensation for unexhausted manurial value from four years to three.

Reconsiderations, 1913—Voelcker and Hall published a revision of their tables in 1913. One reason for the revision was the alteration in the price of fertilisers which had taken place since 1902. Alterations on these grounds are inevitable from time to time, and should be made more or less automatically. There were, however, more fundamental alterations in the 1913 table.

In the first place, it was considered that the allowance to the manure of all the potash in the feeding stuff was too generous, and that a certain loss, particularly in the drainage of urine, does take place in the average case. They, therefore, recommended that three-quarters of the potash in the feeding stuff should be credited to the manure, and that the potash should therefore be dealt with in the same manner as phosphoric acid.

Another important amendment was made in the period over which compensation should be paid in respect of unexhausted manurial values of feeding stuffs. It was pointed out that the nitrogen from

FEEDING STUFFS, THE MANURIAL VALUE OF (*Continued*)—

No.	Foods.	Valuation per Ton as Manure.															Compensation Value for Each Ton of Food Consumed.			
		Nitrogen. A.					*Phosphoric Acid.* B.					*Potash.* C.					D.			
		Per Cent. in Food.	Value at 14s. per Unit.		40 Per Cent. of Value to Manure.		Per Cent. in Food.	Value at 4s. per Unit.		Three-quarters of Value to Manure.		Per Cent. in Food.	Value at 3s. 6d. per Unit.		Three-quarters of Value to Manure.		(1) Before One Crop has been Grown or Removed.		(2) After One Crop has been Grown or Removed.	
			s.	d.	s.	d		s.	d.	s.	d.		s.	d.	s.	d.	s.	d.	s.	d.
1	Decorticated cotton cake	6·90	96	7	38	8	3·10	12	5	9	4	2·00	7	0	5	3	53	3	26	7
2	Undecorticated cotton cake (Egyptian)	3·54	49	7	19	10	2·00	8	0	6	0	2·00	7	0	5	3	31	1	15	6
3	Undecorticated cotton cake (Bombay)	3·10	43	5	17	4	2·50	10	0	7	6	1·61	5	8	4	3	29	1	14	6
4	Linseed cake ..	4·75	66	6	26	7	2·00	8	0	6	0	1·40	4	11	3	8	36	3	18	1
5	Linseed ..	3·60	50	5	20	2	1·54	6	2	4	7	1·37	4	9	3	7	28	4	14	2
6	Soya-bean cake	6·85	95	11	38	4	1·30	5	2	3	11	2·20	7	8	5	9	48	0	24	0
7	Palm-nut cake ..	2·50	35	0	14	0	1·20	4	10	3	7	0·50	1	9	1	4	18	11	9	5
8	Coconut cake ..	3·40	47	7	19	0	1·40	5	7	4	2	2·00	7	0	5	3	28	5	14	2
9	Earth-nut cake ..	7·62	106	8	42	8	2·00	8	0	6	0	1·50	5	3	3	11	52	7	26	3
10	Rape cake ..	4·90	68	7	27	5	2·50	10	0	7	6	1·50	5	3	3	11	38	10	19	5
11	Compound cakes, meals, etc.:																			
	(*a*) Exceeding 15, but not exceeding 20 per cent. albuminoids																			
	(*b*) Exceeding 20, but not exceeding 25 per cent. albuminoids																			
	(*c*) Exceeding 25, but not exceeding 30 per cent. albuminoids																			
	(*d*) Exceeding 30 per cent. albuminoids																			
12	Beans	4·00	56	0	22	5	1·10	4	5	3	4	1·30	4	7	3	5	29	2	14	7
13	Peas	3·60	50	5	20	2	0·85	3	5	2	7	0·96	3	4	2	6	25	3	12	7
14	Wheat	1·80	25	2	10	1	0·85	3	5	2	7	0·53	1	10	1	5	14	1	7	0
15	Barley	1·65	23	1	9	3	0·75	3	0	2	3	0·55	1	11	1	5	12	11	6	5
16	Oats	2·00	28	0	11	2	0·60	2	5	1	10	0·50	1	9	1	4	14	4	7	2
17	Maize	1·70	23	10	9	6	0·60	2	5	1	10	0·37	1	3	1	0	12	4	6	2
18	Rice meal ..	1·90	26	7	10	8	0·60	2	5	1	10	0·37	1	3	1	0	13	6	6	9
19	Locust beans ..	1·20	16	10	6	9	0·80	3	2	2	5	0·80	2	10	2	1	11	3	5	7
20	Malt	1·82	25	6	10	2	0·80	3	2	2	5	0·60	2	1	1	7	14	2	7	1
21	Malt culms ..	3·90	54	7	21	10	2·00	8	0	6	0	2·00	7	0	5	3	33	1	16	6
22	Bran and other offals of wheat	2·50	35	0	14	0	3·60	14	5	10	10	1·45	5	1	3	10	28	8	14	4
23	Brewers' grains (dried)	3·30	46	2	18	6	1·61	6	5	4	10	0·20		8		6	23	10	11	11
24	Brewers' grains (wet)	0·81	11	4	4	6	0·42	1	8	1	3	0·05		2		1	5	10	2	11
25	Clover hay ..	2·40	33	7	13	5	0·57	2	3	1	9	1·50	5	3	3	11	19	1	9	6
26	Meadow hay ..	1·50	21	0	8	5	0·40	1	7	1	2	1·60	5	7	4	2	13	9	6	10
27	Wheat straw ..	0·45	6	4	2	6	0·24	1	0		9	0·80	2	10	2	1	5	4	2	8
28	Barley straw ..	0·40	5	7	2	3	0·18		9		6	1·00	3	6	2	7	5	4	2	8
29	Oat straw ..	0·50	7	0	2	10	0 24	1	0		9	1·00	3	6	2	7	6	2	3	1
30	Mangels	0·22	3	1	1	3	0·07		3		2	0·40	1	5	1	1	2	6	1	3
31	Swedes	0·25	3	6	1	5	0·06		3		2	0·22		9		7	2	2	1	1
32	Turnips	0·18	2	6	1	0	0·05		2		1	0·30	1	1		9	1	10		11

Reproduced from the *Journal of the Ministry of Agriculture and Fisheries*, August, 1927, by permission of H.M. Stationery Office.

FEEDING STUFFS, THE MANURIAL VALUE OF (*Continued*)—

purchased feeding stuffs appears for the most part in the liquid excreta in such relatively simple compounds as urea, which readily give rise to ammonia, the effect of which does not last for more than two years. Rothamsted experiments were quoted as giving practical support to this view. The authors, therefore, proposed to limit the period over which compensation should be considered to two years, and to assess the value of a feeding stuff on the basis of half the value of its nitrogen, three-quarters of the value of its phosphoric acid and potash, and assume that 50 per cent. of this value remained in the soil after one crop had been grown.

A further feature of the 1913 paper is the special consideration of the case in which the food is consumed on the land. Here, it was argued, the losses of nitrogen will not be so great as where the manure is first "made," and it was proposed to allow 70 per cent. of the total manurial value of the nitrogen of the feeding stuff, instead of 50 per cent., but to retain the same assessment after one crop has been grown.

Reconsiderations, 1927—Within recent years a Joint Committee, including representatives of the agricultural chemists and various professional bodies, has further reconsidered the manurial value of feeding stuffs, and its report was published in 1927. The general principles upon which Voelcker and Hall's tables are based were considered to require no change. In the light of further experimental evidence, however, the Committee suggests that 40 per cent. instead of 50 per cent. of the nitrogen in feeding stuffs should be credited to the manure, and that one-half of this should be regarded as still available after one crop has been grown. It was further suggested that no discrimination should be made between the case of food fed in yards and food fed on the land. The Committee did, however, recommend that special consideration should be given to the lower manurial value of feeding stuffs fed to dairy cows, and that at least 25 per cent. of the allowance otherwise made should be deducted when feeding stuffs are fed to dairy cows. In accordance with these recommendations the tables were once more revised, and are here printed in their revised form.

It must be repeated and emphasized that at no stage in their history have these tables been intended to be used automatically in assessing compensation. They are designed as a general basis upon which valuers may proceed, and a vast variety of special considerations may clearly arise in any individual case.

N. M. C.

FERTILIZERS—The writer of the article Manuring, Principles of, defines the meaning of the word "fertilizer" as a substance applied to the soil on account of some plant food it contains—while the word "manure" implies some benefit conferred on the soil itself in addition to that derived from the plant food the manure may contain.

To permit of easy reference, and to avoid the subdivisions necessitated by the fact that many fertilizers and manures contain more than one kind of plant food, the various manures and fertilizers

FERTILIZERS (*Continued*)—

in general use are all arranged alphabetically under the one main heading "Fertilizers."

AMMONIUM CHLORIDE (MURIATE OF AMMONIA)—This salt, which contains 26 per cent. of nitrogen, is used to some extent on the Continent, and may be manufactured in this country.

Until recent years the ammonium salts used in the classical Rothamsted experiments consisted of a mixture of ammonium sulphate and ammonium chloride in equal proportions. The latter, therefore, may be said to have a long history as a nitrogenous manure. Its fertilizing value has been carefully compared with that of sulphate of ammonia in a range of crops (*Roth. Rept.*, 1925-26, 1927-28), the results over the period 1925-1928 being:

VALUE OF CHLORIDE WHEN SULPHATE = 100.

Rothamsted:	Wheat, 7 experiments	106
	Barley, 6 experiments	109
,,	Oats, 5 experiments ..	102
Woburn:	Sugar-beet, 4 experiments	104
Various centres:	Sugar-beet, 4 experiments	100

Although the individual experiments have frequently shown no significant difference between the two forms of nitrogen, where real differences have been observed they have usually been in favour of the chloride. The whole evidence goes to show that the nitrogen in this salt is at least as effective as in the better-known form. For malting barley the chloride has given slightly better yields of rather lower nitrogen content than the sulphate. It may be used exactly as sulphate of ammonia.

BASIC SLAG—This substance is the finely ground slag produced in the manufacture of steel from phosphatic iron ores. Three distinct materials are included in the term basic slag: (1) Slag from the Bessemer steel-making process, containing approximately 18 per cent. of phosphoric acid, of which over 4 million tons metric were produced in Europe in 1927. Great Britain itself was a big producer of this type of slag before the war, but in recent years the Bessemer process has been superseded in this country by the open hearth process. Slags of this kind can only be obtained from the Continent. (2) British-made basic slags containing from 10 to 17 per cent. of phosphoric acid produced by the open hearth process, without the use of fluorspar. (3) British-made open hearth slags containing from 12 to 15 per cent. phosphoric acid made with the addition of fluorspar. In 1928-9 some 300,000 tons of home-produced slags were ground for fertilizer purposes.

The value of basic slag rests mainly on its content of phosphoric acid, the availability of which is measured by the amount of the total phosphoric acid which is dissolved by a 2 per cent. solution of citric acid under standard conditions. The citric solubilities of the three classes of slag mentioned above are approximately:

Bessemer slags	80 per cent. or over
Open hearth slags without fluorspar ..	80 ,, ,, ,,
Open hearth slags with fluorspar	40 ,, ,, or under

FERTILIZERS (*Continued*)—

Recent work on the agricultural behaviour of slags in relation to their citric solubilities indicates that the citric test is a close guide to the field performance until a level of 60 per cent. solubility is reached, above which the value of the slags is less in accord with their solubility figures.

Field experiments with the various types of basic slag have shown that the open hearth slags made without fluorspar are as effective as the pre-war Bessemer slags, when compared on a basis of equal amounts of phosphoric acid. The fluorspar slags, although useful, are not so quick to act as the types of higher solubility. A further type of low soluble slag is now being produced, of which the fluorine content is lower and insufficient to account for their low citric solubility (20-30 per cent.). The agricultural value of these new slags may be higher than the older fluorspar type (*J.R.A.S.E.*, "Agricultural Research in 1928," p. 138). Fortunately, the present-day tendency is to restrict the use of fluorspar, and the greater proportion of slag ground in this country is now highly soluble, and may readily be obtained carrying the guarantee of 80 per cent. citric solubility.

The lime content of basic slags, about 45 per cent. in all, is noteworthy. Some of this is combined with the phosphoric acid, while the remainder, present as calcium silicate and to a small extent as free lime, has neutralizing value. From one-quarter to one-third of the weight of a dressing of slag may be regarded as lime (CaO) equivalent, and is no doubt a factor in improving the lime status of soils to which it is applied. The effect of basic slag in increasing the exchangeable calcium in soils has been observed on a field scale in Wales (R. Williams, *J. Agric. Sci.*, xvi., 1926). Pot experiments have shown definite reduction in soil acidity, following dressings of slag at ordinary agricultural rates.

The manganese contained in basic slags may be of value on certain American soils so deficient in this element that the crops show chlorotic symptoms, but such soils are seldom met with in this country. Fluorine present in quantities of from 0 to 1 per cent. is responsible for immobilizing a corresponding amount of phosphorus as fluor apatite, and is thus a detrimental constituent of basic slags.

The nature of the compounds contained in basic slag has received much study. From the agricultural standpoint the important facts are that there is always more base (calcium) present than corresponds to tribasic phosphate of lime, and that the excess of base is in an active condition. Most of the phosphorus compounds, silicophosphates, and basic phosphates of calcium are dissolved in the soil water and provide an available supply of phosphate for agricultural crops. In the low soluble slags there are more resistant compounds, whose phosphate is insoluble in citric acid and of low availability, *e.g.*, fluor apatite.

The agricultural reputation of basic slag in this country has been built up on the wonderful results obtained on poor, heavy land pastures. When applied in dressings providing about 100 lbs. phosphoric acid per acre, the bulk and, in particular, the quality of such pastures as

FERTILIZERS (*Continued*)—

measured by the growth of leguminous plants is so much improved that the stock-carrying capacity is frequently doubled. Numerous experiments and wide experience have shown that on an extensive range of clay-land pastures basic slag forms the most profitable means of improvement. On the more fertile loams the effect of slag, although usually marked, is not so striking, and on chalky pastures potash salts are sometimes needed in addition to slag.

It is now known that the feeding value of grass is largely bound up with its content of minerals, especially of phosphoric acid and lime. There is evidence that basic slag in common with other phosphatic fertilizers increases the percentage of these constituents in the herbage. This action is specially pronounced on poor or worn-out soils (J. B. Orr, " Minerals in Pasture," London, 1929).

On matted pastures preliminary cultivation is advisable to open the surface before application. A heavy initial dressing of 200 lbs. P_2O_5 is more effective than its equivalent in divided applications, and when the effect has worn off after a period of years, successive dressings providing half the quantity of phosphate usually serve to maintain the improvement. Lime is required in addition to basic slag only on the most acid types of grassland. In ordinary cases the lime content of the slag is sufficient. The phosphoric acid in basic slag is usually regarded as being held up in the top soils until extracted by the plant. This is, broadly speaking, the case, although it has been shown that in very wet districts on acid soils an appreciable amount of leaching takes place (G. W. Robinson and Jones, *J. Agric. Sci.*, xvii., 1927). On the Continent basic slag is used extensively for arable crops, and there is reason to believe that its use for this purpose could be extended in England, particularly on soils where its effective lime content is beneficial. There is no doubt that a high-soluble basic slag is a quick-acting source of phosphoric acid, and quite suitable for seed-bed applications to arable crops.

Under the Fertilisers and Feeding Stuffs Act, 1926, basic slag is sold with a guarantee of the percentage of total phosphoric acid and also of its degree of fineness—usually 80 per cent. passing the standard sieve—the apertures of which are practically identical with the 90 I.M.M. and the Amandus Kahl 100 E sieves. The guarantee of citric solubility is not compulsory, but is becoming customary for slags of over 80 per cent. solubility. (See Fertilisers and Feeding Stuffs Act.)

General Reference—Reports of the Permanent Committee on Basic Slag. *Min. Agric.*, Misc. Pub., No. 30.

BONE MANURES—Bones have been used as a manure from the earliest times. Originally they were applied to the land either whole or coarsely ground, but in modern times methods have been developed for extracting the valuable fat and gelatinous substances, and for increasing the availability of the phosphoric acid by fine grinding or treatment with sulphuric acid. At the same time, following the work on mineral nutrition of live stock, an increasing quantity of sterilized

FERTILIZERS (*Continued*)—

bone products is being used for feeding. Raw bones are very variable in composition, but contain about 20 per cent. phosphoric acid as calcium phosphate, 4 per cent. nitrogen as gelatinous substances, 5 per cent. chalk, 10 per cent. fat and 10 per cent. moisture. The fat has commercial value, but delays the assimilation of the phosphate by plants, so that practically no raw bone meal is now made. When the fat is removed the resulting ground product is known as bone meal, and contains about 20 per cent. phosphoric acid and 4 per cent. nitrogen. If the gelatinous substances are also removed for glue manufacture by steaming under pressure, and the residue finely ground, steamed bone flour is produced containing approximately 27 per cent. of phosphoric acid and 1 per cent. nitrogen.

Degreased bones may be ground and treated with less sulphuric acid than is required to decompose the whole of the calcium phosphate. The resulting product is dissolved bones. The composition varies, but a common grade contains 6½ per cent. soluble, 8 per cent. insoluble phosphoric acid, and 2½ per cent. nitrogen. If steamed bones have been treated in this way the proportion of nitrogen will fall to about 1 per cent. In this process not only is the availability of the phosphoric acid improved, but some of the nitrogen is converted into less resistant forms.

Of the above bone fertilizers, steamed bone meal and the still finer grist, steamed bone flour, are the most important, about 34,000 tons being used each year in the British Isles. Owing to its fine state of division the flour is a more active source of phosphate than bone meal, and is quite suited for arable purposes in the lighter soils which are not well supplied with lime; thus on the light land at Woburn it has given good results on seeds hay. It has also acted well on light soils for grassland improvement (*Mid. Agric. Coll. Bull.*, No. 24, 1929). The use of about 12 per cent. of steamed bone flour in potato mixtures as a drier is a common practice. It is not clear that the slower acting phosphate has any special value for potatoes, but the mechanical effect of the bone flour is good (*Kirton Rept. Expts.*, 1927).

On the heavier soils dissolved bones and bone meal have compared rather unfavourably with basic slag for grass-land improvement and with superphosphate for arable purposes, when the price of the manure is taken into account. At Cockle Park (*Cockle Park Bull.*, No. 42, 1929) they were inferior to basic slag on pasture. At Saxmundham they were no better than superphosphate together with equivalent nitrogen as sulphate of ammonia for hay, and inferior to superphosphate for arable crops (*E. Suffolk Dept.*, Circ. 25, 1927).

The results with hay over a twenty-year period were:

No manure	9·8 cwts.
Superphosphate	22·5 ,,
Superphosphate + sulph. ammonia	25·4 ,,
Bone meal	21·0 ,,

For arable purposes on the heavy soil at Rothamsted bone meal has showed no marked superiority to other forms of phosphate either in

FERTILIZERS (*Continued*)—

immediate or residual effect. The results for the period 1904-1922, inclusive, on a rotation of crops were:

AVERAGE YIELD OF DRY MATTER: NO PHOSPHATE = 100.

	Superphosphate.	*Basic Slag.*	*Bone Meal.*
First year	117	115	113
Second year (residue)	110	115	111
Third year (residue)	112	107	108
Fourth year (residue)	106	112	105

Bone meal is much used for market-garden crops, hops, fruit, and horticultural purposes. For purely agricultural crops the cheaper phosphates will usually have the preference. There is nothing to show that the nitrogen in bone fertilizers has any higher value for ordinary crops than the nitrogen of inorganic salts.

Bone meal is used as a conditioner in mixed fertilizers. When the proportion of phosphate so added becomes considerable, bone compounds are produced, providing phosphate and nitrogen of different degrees of availability.

GENERAL REFERENCE.—Collins, "Chemical Fertilisers," London, 1920.

CALCIUM CYANAMIDE—The manufacture of this substance by Frank and Caro in 1904 was the first case in which atmospheric nitrogen was fixed solely for agricultural purposes. Calcium carbide is produced from lime and coke and caused to combine with nitrogen derived from the air to give calcium cyanamide, $CaCN_2$. The crude product contains 58-60 per cent. calcium cyanamide providing 20-22 per cent. nitrogen. There is also from 20 to 28 per cent. free lime in addition to the 42 per cent. of lime which comes into circulation on the decomposition of the cyanamide. The total effective lime content is therefore 60-70 per cent. The remainder consists of 9-12 per cent. carbon and traces of calcium carbide.

Calcium cyanamide is made in considerable quantities in Europe and North America; the world production in 1927 was 983,000 metric tons. Large amounts are used direct on the Continent, and in mixed fertilizers in the United States. The British consumption, although still small, is increasing.

On application to the soil, calcium cyanamide is transformed into free cyanamide, H_2CN_2, which hydrolyses to urea, $CO(NH_2)_2$. So far, the changes are chemical. The urea then undergoes the usual bacteriological transformation into ammonium carbonate, nitrite, and finally nitrate (*J. Agric. Res.*, xxviii., 1924). The rapidity of the conversion of calcium cyanamide has been shown to depend on the soil type. There is occasionally a considerable delay in nitrification after all the cyanamide has reached the ammonia stage. Neverthe-

FERTILIZERS (*Continued*)—

less, plant growth is well maintained, the crops possibly utilizing ammonia nitrogen (*Roth. Rept.*, 1927-28).

Free cyanamide, in presence of weak alkalis, polymerizes to give dicyanodiamide, $H_4C_2N_4$. This substance has attracted considerable attention because it is a plant poison and exerts a repressing effect on the nitrifying organisms (G. A. Cowie, *J. Agric. Sci.*, vol. ix., 1919). It was present in appreciable quantities in the older forms of cyanamide, and is always liable to increase in amount on prolonged storage in moist conditions (*J. Ind. Eng. Chem.*, xvii., 1925). The presence of this substance in calcium cyanamide was a drawback to its use, and no doubt accounted, in part, for its somewhat uncertain action. It is claimed that modern methods of manufacture turn out a product practically free from dicyanodiamide. The fertilizing action of cyanamide is more dependent on the soil type, the crop, the rate of the dressing, and the time of application than is the case with most other fertilizers. The figures expressing its action on an equal nitrogen basis in terms of the older nitrogenous manures are therefore very variable. All observers are agreed that on the whole the nitrogen in cyanamide is rather less active than in nitrate of soda or sulphate of ammonia. If the action of nitrate of soda be expressed as 100, cyanamide nitrogen has been placed by various Continental experimenters at from 76 to 90 (Schneidewind, *Die Ernährung der Landw. Kulturpflanzen*).

A summary of British results up to 1918 on various crops and soils gives 84-89 as the corresponding figure for this country (*Rept. of the N. Products Ctte.*, 1919). Recent trials conducted from Rothamsted indicate that cyanamide is as effective as sulphate of ammonia for barley, but less so for potatoes or sugar beet, but much data must accumulate before very precise statements are possible.

Cyanamide should be applied in the seed bed, and owing to its somewhat caustic action towards germinating seeds, it is best incorporated a week or two before sowing the crop. It is also extensively used on the heavier soils on the Continent for autumn application to winter corn; on light soils, however, it is better reserved for early spring applications. Owing to its rather slow action and injurious effect on foliage cyanamide is not suitable for top-dressing root crops. It may, however, be applied as an early top dressing to cereal crops if a dry day is chosen for the work.

The agricultural value of the lime content of cyanamide should not be over-estimated. It cannot take the place of the chalking on soils which are dangerously acid. On the other hand, the systematic use of cyanamide does something to balance the annual loss of lime through drainage and crop removal.

Cyanamide mixes readily with basic slag, rock phosphate, and potash salts, but owing to its free lime it should not be mixed with sulphate of ammonia. When cyanamide and superphosphate are mixed, some water-soluble phosphate is reverted and a certain amount of dicyanodiamide is formed. The small percentage of cyanamide which is frequently put into factory-made mixtures does not undergo the above change to any appreciable extent (*J. Ind. Eng. Chem.*, xvi., 684, 1924).

FERTILIZERS (*Continued*)—

The dusty character of cyanamide has recently been somewhat improved by the addition of about 1 per cent. of mineral oil. It is still best applied, however, with a distributor. Unoiled cyanamide is extensively used on the Continent to kill charlock in cereal crops, the powder being applied as a dust-cloud when the herbage is wet with dew. The cereals are not permanently damaged, and benefit from the manurial effects of the cyanamide.

CONCENTRATED FERTILIZERS—In recent years a series of compound manures of exceptionally high analysis have been developed in Germany (A. Mittasch, *Zeitschr. f. Angewandte Chem.*, 41, 1928). The substances on which they are based are ammonium nitrate (35 per cent. N), di-ammonium phosphate (53 per cent. P_2O_5, 21 per cent. N), urea (46 per cent. N), potassium nitrate (14 per cent. N, 47 per cent. K_2O), and high grade potash salts. The nitrogen is in all cases synthetic. A combination of ammonium nitrate, di-ammonium phosphate, and high grade chloride, or in certain cases sulphate of potash, is sold in large quantities on the Continent under the name of Nitrophoska, a certain amount of which has been used experimentally in this country. It is put out in several grades of the following composition:

	N per Cent.	*P_2O_5 per Cent.*	*K_2O per Cent.*
For cereals (high nitrogen) ..	17·5	13·0	22·0
For roots and light soils (high potash)	15·0	11·0	26·5
For soils poor in phosphoric acid	16·5	16·5	20·0
For cotton in U.S.A.	15·0	30·0	15·0
For tobacco (free from chlorine)	15·5	15·5	19·0

Much experimental work has been done with mixed fertilizers of the above type on the Continent, but in England accurate comparisons are as yet few. At Woburn, Nitrophoska gave much the same results on potatoes as did equivalent nutrients in the standard forms (*Roth. Rept.*, 1927-28).

Other substances of a similar type are Harnstoff-Kaliphosphor (28 per cent. N, 14 per cent. P_2O_5, 14 per cent. K_2O), which contains urea, potassium nitrate, and di-ammonium phosphate; and Leunaphos (20 per cent. N, 20 per cent. P_2O_5), containing sulphate of ammonia and di-ammonium phosphate.

FARMYARD MANURE—This is still by far our most important fertilizer. The problems which it presents are how to conserve its rather fugitive manurial properties, and how to use the limited quantity available to the best advantage.

In order to approach these questions it is necessary to consider the nature of the litter and solid and liquid animal excrements which go to make up farmyard manure.

The litter (usually straw) is poor in manurial constituents, containing approximately 10 lbs. of nitrogen, 5 lbs. of phosphoric acid, and 18 lbs. of potash per ton. Moreover, the nitrogen and phosphate are only slowly available, although much of the potash is water-

FERTILIZERS (*Continued*)—

soluble and therefore passes readily into circulation. The litter, however, provides a considerable quantity of the organic matter with which the well-known textural improvement resulting from the use of farmyard manure is associated. The organic matter of the original straw consists of a series of carbohydrates of widely different degrees of resistance to the rotting process which is the essential feature of dung-making. The sugars and starches are easiest attacked by the micro-organisms responsible for the change; the pentosans and cellulose come next, whilst the lignin (woody material) is exceedingly resistant to change and comparatively little affected, even after prolonged rotting. The solid excretæ of the animals consist of materials which have resisted the action of digestive processes in the alimentary canal and are, therefore, a source of relatively unavailable plant food. They contain a proportion of organic matter, the undigested residues of coarse fodders, which contribute materially to the bulk of the manure, and an enormous number of bacteria—several thousand millions per gram—mostly intestinal forms. The urine, regarded from the manurial standpoint, consists of a weak solution of relatively simple nitrogen compounds (mainly urea), in addition to potash compounds, but practically no phosphoric acid. The nitrogen and potash of the urine are readily available to plants, and some 80 per cent. of the manurial value of digestible foods, such as cake and roots, fed to stock, is associated with the urine as distinct from the solid excretæ (C. Crowther, *Trans. H. Agric. Soc.*, 1910). On exposure to the air, the urea undergoes a rapid transformation by the agency of bacteria into ammonium carbonate, from which ammonia is evolved; this action forms the most serious source of loss in dung management. When the various solid and liquid constituents of farmyard manure are brought together a rotting process begins, consisting essentially in the breaking down of the more easily attacked compounds of the straw by countless bacteria, which utilise the carbohydrate matter as a source of energy, at the same time deriving their nitrogen requirements from the ammonia compounds provided by the urine. With free aeration this change proceeds briskly accompanied by considerable rise of temperature (60° C. is frequently attained) and loss of organic matter, the carbon passing off as carbon dioxide. If air is excluded by pressure or as a result of displacement by gaseous products the fermentation is not completely stopped, but continues by the agency of anaerobic organisms, at a slower rate. (See Nitrification.)

The ratio of carbon to nitrogen has a considerable influence on the loss of ammonia which always takes place to some extent in the rotting of farmyard manure. It has been shown that straw has a saturation capacity for soluble nitrogen compounds—it can transform about 16 lbs. of nitrogen into the organic form for every ton of straw present (H. B. Hutchinson and E. H. Richards, *J. Min. Agric. and Fish.*, Aug., 1921). If more than this amount of nitrogen is given loss of ammonia is sure to take place; if less, the fermentation proceeds more slowly, but the nature of the final product is much the same. On the balance it is

FERTILIZERS (*Continued*)—

important to see that there is sufficient litter for the stock, otherwise not only will the straw be overloaded with nitrogen, but some of the liquid manure will probably run to waste. There is also an optimum concentration of soluble nitrogen compounds from the point of view of the rotting process, and it is noteworthy that the most dilute urine produced under farm conditions exceeds this strength.

The rotting of farmyard manure is an essential process. It removes from the straw the easily decomposable carbohydrates which would otherwise be broken down in the soil by micro-organisms, using for that purpose the supply of available nitrogen and phosphoric acid which should go to the growing crop. This action is the cause of the depressing effect on a crop following an application of raw straw or unrotted farmyard manure. Further, the above carbohydrates react unfavourably on the nitrifying organisms and their removal is desirable on these grounds. The rotting process also favours the breakdown of the more readily decomposable protein substances in the solid dung, and prepares them for nitrification. (See Farmyard Manure, Synthetic.)

We must now examine the extent of the losses involved in the rotting process, and how far they may be minimized by good management.

Under no conditions of ordinary farm storage has the loss of nitrogen fallen below about 15 per cent. of the quantity originally present. Thus, in several of the classical experiments on this subject the losses have been:

Centre.	*Loss of Original Nitrogen, per Cent.*
Woburn (mean of three seasons)	22·3
West of Scotland Agricultural College ..	19·9
Cambridge (mean of two samples)	18·7
Wye (mean of two samples)	14·4
Mean	18·8

Although this loss is at present regarded as the minimum in ordinary practice it is noteworthy that in laboratory experiments where the conditions were completely anaerobic no loss of nitrogen was observed; and in heaps of very compact cow manure very small loss occurred (E. J. Russell and E. H. Richards, *J. Agric. Sci.*, vol. viii., 1917). For the purposes of tenant right valuation, Hall and Voelcker assume that only 50 per cent. of the nitrogen of the food is recovered in the stored manure, even taking into account the proportion of the nitrogen retained by the stock for growth, or used for milk production. This implies a considerably greater loss of nitrogen under ordinary management than occurred in the experiments quoted above. These authors state, however, that if the dung has suffered undue exposure or movement the allowance should be correspondingly reduced, but should never fall below one-half of the normal figure (*J.R.A.S.E.*, vol. lxxix., 1913. See also Feeding Stuffs, Manurial Value of).

Fermentation also involves a loss of dry matter, part of which at any rate is an advantage (the sugar, starch, and pentosans). It is favoured by aeration and is then accompanied by a considerable rise

FERTILIZERS (*Continued*)—

in temperature. Thus, in storing bullock manure for eight months at Rothamsted the following losses were observed:

	Loss of Dry Matter, Per Cent.	*Maximum Temperature.*
Compact storage	30	35° C.
Loose storage	51	71° C.

A further factor restricting the loss of dry matter, and of nitrogen, is the provision of shelter for the manure, and this acts beneficially on loose and compact heaps alike. Typical figures for the storage of various manures are:

Rothamsted: Bullock Manure, Nine Months' Storage.

	Loose Heap.		*Compact Heap.*	
	Exposed.	*Covered.*	*Exposed.*	*Covered.*
Loss of dry matter, per cent.	60	45	60	47·5
Loss of nitrogen, per cent.	51	32	50	42

Kilmarnock: Cow Manure, Four Months' Storage, Compact Heaps.

	Exposed.	*Covered.*
Loss of dry matter, per cent.	23	11
Loss of nitrogen, per cent.	28	20

All experience shows that moist and tight storage produces the least wastage. The exclusion of air by compression, by moisture, or by the accumulation within the heap of carbon dioxide, restricts excessive fermentation and loss of dry matter and ammonia. Deep boxes, covered yards and dungsteads, and sheltered clamps, all assist in the same direction.

Apart from fermentation losses, the wastage due to the draining away of soluble substances must be considered. This is a comparatively simple problem, and can be overcome completely by suitable arrangements in buildings and yards. Dung contains a considerable proportion of soluble, and therefore readily available constituents, mainly derived from the urine of the stock. Thus, in analyses carried out at the West of Scotland Agricultural College (*West of Scot. Coll. Bull.*, No. 65), the following amounts are shown:

FERTILIZERS (*Continued*)—

FRESH COW MANURE.

Percentages of Total Nitrogen, Phosphoric Acid, and Potash which are Water Soluble.

Nitrogen	26·6 per cent.
Phosphoric acid	41·9 ,, ,,
Potash	76·0 ,, ,,

The greater part of loss arising from the presence of these substances can be prevented at the source by collecting and using the liquid manure separately, particularly in the case of stables and cow stalls. (See Liquid Manure.)

Farmyard Manure as a Fertilizer—The average composition of farmyard manure is:

	Total Nitrogen.	*Ammonia Nitrogen.*	*Amide Nitrogen.*	*Other Nitrogen.*	*Phosphoric Acid.*	*Potash.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Bullock dung	0·62	0·12	0·08	0·42	0·26	0·72
Cow dung	0·43	0·09	0·03	0·29	0·19	0·44
Horse dung	0·54	0·13	0·04	0·34	0·23	0·54

It is a complete fertilizer in which the nitrogen is the most valuable constituent, both from the monetary and the crop-producing standpoints. The proportion of ammonia nitrogen can be increased by cake feeding, and also seriously decreased by wrong management. Thus samples of rich cake-fed bullock manure made at Rothamsted contained 0·77 per cent. total nitrogen with 0·18 per cent. ammonia nitrogen, the corresponding figures for store dung being 0·54 and 0·04 per cent. On storage under the best conditions the following losses are on record:

	Loss of Nitrogen, per Cent.
Cambridge, rich dung	26·9
Cambridge, poor dung	10·6
Wye, rich dung	15·4
Wye, poor dung	13·3

The loss falls chiefly on the ammonia nitrogen in both cases. The ammonia and amide nitrogen may be regarded as available to the first crop. Part of the other nitrogen becomes available later, but some is so resistant as to be of very little agricultural value. At Rothamsted the actions of the rich and poor manure have been compared over a four-course rotation. The figures are:

NO DUNG = 100.

	First Year.	*Second Year.*	*Third Year.*	*Fourth Year.*
Rich dung ..	173	143	122	120
Poor dung ..	146	133	123	115

FERTILIZERS (*Continued*)—

The rich manure is greatly superior in the first year, slightly so in the second year, and both manures are about equal in the last two seasons.

Next in order of value to the nitrogen comes the potash, which is mostly water soluble. Its availability may be gauged by comparing the action of potash manures in the presence and absence of dung. Thus, at Rothamsted the addition of 2 cwts. sulphate of potash in the presence of ample nitrogen and phosphate gives on the average the following increases in the potato crop:

Without farmyard manure	36 cwts. per acre
With farmyard manure	15 ,, ,,

Farmyard manure is comparatively poor in phosphoric acid (5 lbs. per ton), and the whole of this cannot be regarded as being rapidly available. In ordinary farm practice it is customary to apply to the soil more phosphoric acid in the form of artificials than is given in the form of dung. This is seldom the case for the other constituents.

The effect of dung in maintaining the lime status of soils is noteworthy. Thus, on the Woburn barley plots the following soil reactions have been determined (E. M. Crowther, *J. Agric. Sci.*, vol. xv., 1925):

	pH.
No manure	5·77
Six tons dung every year	6·28

There is abundant evidence that the dung supply may be usefully supplemented by the addition of artificial fertilizers. This is especially so in so far as its effect on the first crop is concerned. In a long series of experiments conducted in Ireland, the following results were obtained over the years 1901-11 (*J. Dept. Agric. Ireland*, vol. xvii., p. 242, 1917):

Average of 353 *Experiments.*	*Potatoes.* Tons per Acre.
No manure	4·00
15 tons dung	8·20
20 tons dung	9·20
15 tons dung and complete artificials	10·85

In the matter of residual effect the heavy application of dung comes out best, however, as the following figures show: (*West of Scot. Coll. Bull.*, No. 65, 1914).

UNMANURED = 100.

	Turnips.	*Barley.*	*Seeds.*	*Oats.*
20 tons dung	146	119	102	105
10 tons dung	140	107	92	94
10 tons dung and artificials ..	158	107	92	95

There is no doubt, however, that the deficiency in the later years could be met by further additions of suitable fertilizers.

FERTILIZERS (*Continued*)—

The Mechanical Effect of Dung—The effect of farmyard manure in rendering all classes of soils easier to work is well recognized. Determinations of drawbar pull made at Rothamsted on plots continuously manured as compared with those receiving no dung show the following reduction of draft:

	Drawbar Pull (lbs.).	
	Broadbalk Field.	*Great Hoos Field.*
Farmyard manure	964	1,199
No manure	1,049	1,350

There is also a considerable improvement in the water-holding capacity of the top soil due to the use of dung, amounting to an increase of 3 per cent. of water, or approximately, 0·3 inch of rain, in certain cases. Thus, on part of the Broadbalk field, which was fallow in 1928, and therefore free from the disturbing influence of a crop, the moisture content of the top soil in June was:

Plot 2.	Dung every year	20·2 per cent.
,, 8.	Complete artificials every year	16·9 ,, ,,
,, 3.	Unmanured	14·8 ,, ,,

The effect of dung in puffing up the soil, due to the evolution of carbon dioxide by the enhanced activity of the soil micro-organisms, is a great aid to cultivation. It is possible that the carbon dioxide itself may enrich the air in the neighbourhood of the plant and thus increase assimilation, while the carbon dioxide in the soil water assists the attack on the mineral resources of the soil and on insoluble fertilizers, *e.g.*, rock phosphates.

Recent Developments in the Handling of Farmyard Manure—On the Continent several systems of separating the liquid manure from the soluble manure, and of storing and utilizing each of these materials separately have been worked out. Although, undoubtedly, sound in principle, they have not yet made much headway in this country.

There is also the hot fermentation process of Krantz which results in a product called "Edelmist." Here the manure from the stalls is thrown out daily into a loose heap, and every effort made to secure a brisk initial fermentation with consequent high temperature (55°-65° C.). At this high temperature the bacterial numbers are reduced, only thermophilic organisms being numerous. The mass is then compressed as tightly as possible to exclude air, this being accomplished by piling a fresh layer of manure on top of the original one. It is claimed that the loss of nitrogen and dry matter is reduced, and the availability of the nitrogen in the manure increased by the procedure. Specially constructed dungsteads are recommended for this system. In England a system for the artificial rotting of straw has

FERTILIZERS (*Continued*)—

been worked out (H. B. Hutchinson and E. H. Richards, *J. Min. Agric.*, Aug., 1921), whereby the decomposition of the less resistant compounds of the straw is facilitated by providing a suitable nitrogen and phosphate supply, and maintaining a neutral reaction. As previously mentioned, the study of the principles underlying this process has thrown light on several points of dung management.

The cost of handling dung on the farm is considerable, and the development of mechanical methods is urgently required. Dung spreaders are in common use in countries where labour is scarce, and are steadily making headway in this country. Dung conveyors from stalls to yards or dungsteads are also gaining ground. There is further need for improvement in the methods of collecting and distributing liquid manure.

FARMYARD MANURE, SYNTHETIC—The value of organic matter in soil has long been recognized by practical agriculturists. In times past the farmer has been able to maintain his soil in a state of high fertility by the regular application of farmyard manure. In the British Isles, however, during recent years, market conditions have tended to make the keeping of stock, mainly for the production of farmyard manure, increasingly expensive, and there is no sign of any important change. The natural result has been that many thousands of acres have received no dung for a long time past, and the remainder have had less than the quantity necessary to keep the humus content of the soil up to the standard generally recognized by good husbandry.

Under these circumstances alternative means of supplying organic matter, such as green manuring, have been adopted to some extent. There are, however, definite limitations to this method, which is, generally speaking, the cheapest substitute for the dung cart. (See Green Manuring.) Shoddy, sewage sludge, and other organic manures obtained from outside the farm, are also used to a limited extent, but these materials are quite insufficient to meet the needs of much of the arable land which is deficient in humus.

From the earliest times composts made from plant residues, by allowing these to rot down in heaps, have been used to supplement the animal manures produced on the farm. The Chinese have acquired great proficiency in this method, which, together with the careful conservation of all human excrement, has, according to King ("Farmers of Forty Centuries"), alone enabled that country to maintain its vast population. It should be carefully noted that the Chinese farmer never applies *unrotted* vegetation to his soil. Only in this way can he raise the three crops a year without which he must starve.

In 1921, Hutchinson and Richards (*J. Min. Agric. and Fish.*, vol. xxviii.) described laboratory experiments on the production of an artificial farmyard manure from straw, which were subsequently developed on the commercial scale as the Adco process. The tissue of mature plants is rich in carbohydrate and deficient in nitrogen

FERTILIZERS (*Continued*)—

—particularly in biologically available nitrogen—so that the average ratio of carbon to nitrogen approximates 30 : 1. Before the straw can be of any use in promoting crop growth, the carbon-nitrogen ratio must be reduced to less than 20 : 1. Since the fungi, which are the most active agents in breaking down the cellulosic material, require available nitrogen, phosphate, and a little potash for building up their own cell structure, there is a temporary holding up of these elements while the raw straw is being digested. Hence a depression of crop yield is generally observed when raw straw is applied to fertile soil.

The same reactions occur in the manure heap, but as the temperature and other conditions are then much more favourable to rapid loss of carbon, the correct C/N ratio is more easily attained than when the straw is in contact with soil only. In the farmyard manure heap the urine in the fresh manure usually provides a considerable excess of nitrogen over the definite quantity which can be assimilated and retained by the straw against loss by volatilization or leaching. (See Farmyard Manure.)

The quantity of available nitrogen which can be assimilated by 100 parts of the cellulosic material is known as the "nitrogen factor." This figure has been determined by numerous tests on most of the waste products found in agricultural production at home and abroad. It varies from 0·5 to 1·5, according to the carbohydrate content and age of the sample. Wheat, oat, barley, and rye straws require from 0·7 to 0·8 part of nitrogen per 100 parts of dry material to ensure the thorough breakdown of the straw. If any larger quantity of nitrogen is added it is liable to loss by leaching or volatilization as ammonia. If less is used the straw will not be completely humified, and the final product will contain less than the normal percentage of all the three substances, nitrogen, phosphoric acid, and potash, owing to the presence of undigested cellulose.

By the practical application of the principles outlined above, large quantities of organic manure have been produced during the past few years in different parts of the world. In 1930 about 50,000 tons of finished manure were made by the use of the special reagents prepared by Adco Ltd. and its licensees. These are used at the rate of 1 to 1½ cwts. per ton of dry matter in the form of straw or other waste vegetation, according to the nitrogen factor and the quality of the manure required. The bacterial stimulants supply sufficient nitrogen, phosphate, and potash to ensure a rapid start to the fermentation, maintain the necessary alkaline reaction, and yield a final manure of an analysis shown in the first table on p. 361.

The only difficulty encountered in producing manure in quantity arises from the slowness with which straw in the long, unbroken state will absorb the amount of water necessary for the proper rotting of the heap. One ton of straw requires 800 gallons of water to bring it to the optimum moisture content of 75 per cent. Long straw will not absorb more than one-quarter of this volume of water as it is sprayed on to the layers in which the heap is built up; the rest of the water

FERTILIZERS (*Continued*)—

must be added at intervals, after the temperature has risen to 30° C. Alternatively, rainfall may be relied on to supply all the water required. In this case a layer of straw, and its proper proportion of chemical stimulants, must be allowed to become saturated and well consolidated by drawing a cart over it, in the way usual with dung clamps, before the next layer is placed in position. The whole heap may thus take six months to build up, and the manure will not be ready for use until the last layer has had three or four months to rot down. A rainfall of 12 ins. between October and March is ample for this method of wetting the straw, which is then usually more uniformly moistened throughout the heap than when artificial watering is employed.

One hundred parts contain—

Manure.	*Water.*	*Organic Matter.*	*Nitrogen.*	*Phosphoric Acid.*	*Potash*
Dung of average quality ..	76·1	18·9	0·53	0·23	0·56
Synthetic farmyard manure from:					
Wheat straw	75·0	14·00	0·60	0·42	0·19
Barley straw	80·6	13·00	0·63	0·33	0·37
Rye	80·0	15·89	0·53	—	—
Bean haulm	87·12	9·63	0·42	0·19	0·39
Spoilt hay	81·58	11·94	0·56	—	—
Hop bine	76·9	13·4	0·41	0·32	0·30
Bracken	81·81	11·30	0·50	0·41	0·29
Garden refuse	63·7	16·3	0·55	0·94	1·25

A large number of plot trials of synthetic farmyard manure has been made at official agricultural experiment stations in different parts of the world. As a rule the crop yields are very close to those given by an equal dressing of good farmyard manure, but occasionally they have been significantly higher. A few of the more important trials are summarized below:

POTATOES.

	Manure.	*Artificials.*	*Yield of Crop.*
	Per Acre.	Per Acre.	Per Acre.
1. Adco manure with artificials ..	12 tons	6½ cwts.	12 tons 11 cwts.
2. Dung with artificials	12 ,,	6½ ,,	11 tons 18 ,,
3. Artificials alone	—	6½ ,,	10 ,, 2 ,,

Test at Orsett (Essex). Soil of very high fertility. The season was wet and produced heavy crops. Although artificials were very effective, the dunged plots were superior by 25 and 18 per cent. respectively. The average crop for England was 6 tons per acre.

FERTILIZERS (*Continued*)—

OATS.

	Manure.	*Grain.*	*Straw.*
	Per Acre.	Crop per Acre.	Crop per Acre.
1. Adco manure with artificials ..	15 tons	54 bush.	36 cwts.
2. Bullock manure	21 ,,	46 ,,	31 ,,
3. Adco manure alone	15 ,,	50 ,,	32 ,,
4. Chaffed straw (untreated) with artificials	3 tons 2½ cwts.	34 ,,	28 ,,

Test at Romney Marsh (Kent) in 1923. The artificials in (1) and (4) were arranged to bring the total nutrients up to those on plot (2). The average crop for England in 1923 was 37·6 bushels of grain.
This plot received the same weights of plant nutrient as No. 3, but *without* treatment in stack.

MANGOLDS.

	Crop per Acre.
1. Dung with artificials	21 tons 10 cwts.
2. Adco with artificials	21 ,, 0 ,,
3. Artificials alone	19 ,, 0 ,,
4. No manure	17 ,, 10 ,,

Test at the South-Eastern Agricultural College Farm, Wye (Kent), in 1923. Soil of high fertility. Season not favourable. The average crop for England in 1923 was 17·3 tons per acre.

Weight for weight, synthetic farmyard manure is more bulky than dung, so that from 12 to 15 tons per acre of the former is usually as much as can be conveniently ploughed under in one application; this is equivalent to 20 tons of well-made dung. One ton of straw will yield three tons of "long" manure, or two tons of a rich, cheesy product. The cost of making synthetic farmyard manure will naturally vary with local conditions, but at current prices it is about 7s. per ton of long manure, allowing no value for the straw.

Synthetic farmyard manure has, so far, been used chiefly in horticulture and tropical agriculture—especially on sugar plantations—where the supplies of dung are insufficient. Recently, however, farmers on the Continent have found that Adco manure affords a useful means of utilizing their surplus straw, and considerable interest has been shown in the large-scale trials carried out in Germany and Poland. In these countries, unlike Great Britain, the growing of straw crops is still profitable, while there are not enough animals to convert all the straw into dung. So long as the American prairie farmer can grow his wheat at a profit, without any attempt at manuring his soil, the vast piles of straw there left after harvest will continue to be burnt. The time is perhaps not so distant when he will find that all the virgin soil is taken up, and that without humus he cannot grow good crops. Synthetic farmyard manure may then find its place in the rotation farming which must succeed the present wasteful methods.

E. H. R.

FERTILIZERS (*Continued*)—

GUANO—This is, strictly speaking, the excreta and remains of sea birds which has been deposited in rainless districts. The deposits of Peru, described in 1804 and imported into England in 1840, are of this character. Peruvian guano made a great impression on British farming and references to its excellent action are numerous in the literature of the time (*J.R.A.S.E.*, vol. ii., p. 301, 1841). High-grade guano contains from 10 to 14 per cent. nitrogen, 9 to 11 per cent. phosphoric acid, and 2 to 4 per cent. potash. This grade of guano is exceedingly scarce, and the ordinary grade contains 5 to 8 per cent. nitrogen, 14 to 18 per cent. phosphoric acid, and 2 to 4 per cent. potash. The nitrogen of guano is present in several different forms, of which the most usual are ammonium urate, oxalate, phosphate, and chloride. This gives a range of availability which is believed by practical men to make for steady growth and quality in the produce. The same holds for the phosphoric acid, which occurs as soluble ammonium phosphate and insoluble calcium phosphate.

Experiments on farm crops have not shown guano to be markedly superior to inorganic fertilizers, nor could any residual effect be detected at Rothamsted when 7 cwts. per acre were given at the beginning of a rotation (*J. Min. Agric.*, vol. xxvi., p. 244, 1919). Like most organic manures, its chief application lies in specialized and intensive culture. If guano deposits are washed by rain the soluble constituents are removed and a phosphatic guano is left; such substances contain only about 3 per cent. nitrogen, but 18-32 per cent. phosphoric acid, largely as phosphate of lime. Guanos are now usually treated with sulphuric acid to increase the availability of the phosphate and fix the volatile ammonium compounds. They are also enriched by adding potash salts.

LIQUID MANURE—The conservation and economical use of liquid manure is a problem which has not yet been satisfactorily solved. All are agreed that it has considerable manurial value, but most farmers are reluctant to expend the necessary labour to apply it to the soil.

The composition of liquid manure varies greatly; it is affected by the degree of dilution of the urine of the livestock, either by feeding watery foods such as roots, or by subsequent dilution by wash water or surface water. The richness of the feeding is also reflected in the composition of liquid manure, and finally the extent to which the liquid is exposed to evaporation governs the loss of ammonia. The table on p. 364 gives analyses of urine and liquid manure.

Ordinary liquid manure is therefore more dilute than the urine. Most of the nitrogen present is ammoniacal, there is more potash than nitrogen, and the amount of phosphoric acid and lime is very small. From the purely chemical point of view the best practice is to convey the liquid manure from cow-houses and stables as speedily as possible to a hermetically sealed tank, freeing it from straw, etc., and preventing its dilution by wash water. The liquid is then nearly

FERTILIZERS (*Continued*)—

pure urine. The urea contained in the urine undergoes a very rapid fermentation to ammonium carbonate, which is so liable to lose ammonia on exposure that the liquid is best drilled or lightly ploughed into the ground at once after application. Systems on these lines are being developed on the Continent.

Type of Stock and Character of Feeding.	*Water.*	*Total Nitrogen.*	*Ammonia Nitrogen.*	*Phosphoric Acid.*	*Potash.*	*Lime.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Cattle urine, ordinary feeding	93·8	1·0	—	0·1	1·5	0·3
Horse urine, ordinary feeding	90·0	1·2	—	0·05	1·5	0·15
Cattle urine, heavy turnips, no cake ..	—	0·22	—	—	—	—
Cattle urine, light turnips, with cake ..	—	0·58	—	—	—	—
Cattle urine, heavy mangolds	—	0·12	—	0·01	0·60	—
Cattle urine, lucerne and water	—	1·54	—	0·006	1·69	—
Liquid manure, average of 35 Scotch samples	98·21	0·204	0·179	0·029	0·462	0·019
Liquid manure, average of 191 Swiss samples	—	0·17	0·133	0·03	0·437	—

To meet the requirements of the Milk and Dairies Order, 1926, specifications for liquid manure tanks, suitable to English conditions, must secure that the liquid is stored far enough from the cow-house. About 12 cubic ft. of space is allowed per cow, and arrangements are made for diverting wash water from the tank, which is rendered air-tight (*J. Min. Agric.*, Leaflet No. 382).

Grass and rotation seeds hay are the most suitable crops to receive liquid manure, and experiments in Scotland have shown that it can be applied during the winter months with good effects (J. Hendrick, *N. of Scot. Coll. Bull.*, No. 19, 1915).

AVERAGE OF TEN EXPERIMENTS.

Liquid Manure (per Acre).	*Hay (Cwts. per Acre).*
No manure	40·3
2,000 gallons liquid manure applied December	49·5
2,000 gallons liquid manure applied January-February	51·5
2,000 gallons liquid manure applied March	50·1
1,000 gallons December + 1,000 gallons March ..	51·1
2,000 gallons December + 2,000 gallons March ..	54·2

Note—1,000 gallons weigh $4\frac{1}{2}$ tons.

The value of liquid manure for grassland has also been brought out by an extensive series of trials in Ireland (*J. Dept. Agric. I.*, vol. xvi., 1915), where the results were:

FERTILIZERS (*Continued*)—

AVERAGE OF TWO HUNDRED AND FORTY-NINE EXPERIMENTS.

Manures (per Acre).	*Hay (Cwts. per Acre).*
No manure	41
16 tons dung	57
16 tons liquid manure	58
1 cwt. nitrate of soda 2 cwts. superphosphate 2 cwts. Kainit	57

Here the liquid manure was as effective in the year of application as an equal weight of dung, or a light, complete dressing of artificial manures.

Liquid manure may also be applied in early spring to catch crops such as rye-grass for early keep, or in early summer to cabbages and mangolds. It is best applied in showery weather so that the liquid is washed well into the soil. If used on grassland for a period of years the need for phosphate, and in some cases for lime, becomes pronounced; hence, occasional applications of basic slag are a suitable means of improving the quality of the herbage. The effect of liquid manure on the mineral composition of the grass has been examined in Switzerland, where it is the chief manure used on grassland. The deficiency of lime is reflected in the herbage after a time, but this can be corrected by liming (Leichti, P., *Landw. Jahrb.*, Schwei 2, 1921).

NITRATE OF LIME—This, like calcium cyanamide, was one of the earliest synthetic nitrogen products. It was first manufactured in 1905 at Notodden, in Norway, by the process of Birkeland and Eyde. Cheap water power is essential, as much more energy is required by this than by any other fixation process. Atmospheric oxygen and nitrogen are caused to combine at 3,000° C. in an electric arc, and the resulting oxides of nitrogen are absorbed in water forming nitric acid, which is neutralized with limestone. The final product is calcium nitrate, $Ca(NO_3)_2$, containing 13 per cent. nitrogen and 21·3 per cent. water.

Some 169,000 tons were produced in Norway in 1928, of which 11,000 were imported into Great Britain. Nitrate of lime is also manufactured in Germany by neutralizing nitric acid, made by the ammonia oxidation process, with milk of lime. It is mixed with a little ammonium nitrate, thereby raising the percentage of nitrogen to 15·5.

Nitrate of lime readily takes up water from the air, and the airtight packages in which it is sold should not be opened until required. It is not suitable for use in mixtures. English experiments have shown that the manurial effect of nitrate of lime is similar to that of nitrate of soda, except that, being a calcium salt, it exerts no undesirable effect on the textures of clay soils. An extensive series of German experiments recently gave the same results. The effect on the texture of heavy soils was favourable rather than damaging, but the final yield was the same as with nitrate of soda, even on these soils (Huppert, *Forts. der Landw.*, 1929).

NITRATE OF SODA—The nitrate beds of Chile are distributed along a strip of arid desert lying at the foot of the Andes but separated from the

FERTILIZERS (*Continued*)—

coast by a lower range of hills. The thickness of the beds is very variable, but averages about 4 feet. The nitrate ore, or "Caliche," which is covered by an overburden of varying thickness, contains on the average about 17 per cent. of sodium nitrate mixed with sodium sulphate, sodium chloride, and earthy material. The Caliche with its overburden is blasted out, the ore sorted by hand, and conveyed to the factory. There it is crushed, and the nitrate separated from the other salts and impurities by crystallization from water solution. Until recently the methods of mining and extraction were those practised in the middle of the nineteenth century, and gave a recovery of less than two-thirds of the nitrate in the Caliche. The commercial product contains about 95 per cent. sodium nitrate containing 15½ per cent. nitrogen. The feature of the nitrogen industry in recent years has been the increasing share of the world trade secured by synthetic nitrogenous products. In 1894, approximately 73 per cent. of the world requirements of combined nitrogen came from the Chile deposits; in 1928 the nitrate mines satisfied some 25 per cent. of the world demand only, although the actual output was 2½ times that of 1894 and 90 per cent. of the pre-war production.

In Great Britain the same tendency has been noticeable. In 1913 about twice as much nitrate of soda was used as sulphate of ammonia. By 1929 the proportion had shrunk to about one-third of the sulphate of ammonia consumption. The future of the sodium nitrate industry is bound up with the introduction of more economical systems of mixing and extraction, and progress is already being made in this direction.

Nitrate of soda was first imported into Great Britain in 1831. It was used in the Rothamsted experiments in 1843, and as experience accumulated it became the most popular artificial source of quickly acting nitrogen.

Nitrate of soda is not absorbed by the soil, and supplies the plant with immediately available nitrogen; it is, therefore, best applied after the winter rains are over and when a quick response is required. (See Lysimeters.) Under these conditions it is usually more effective per unit of nitrogen than ammonium salts or more complex nitrogenous fertilizers, ammonia nitrogen generally being assigned 90 per cent. of the effectiveness of nitric nitrogen. The sodium contained in nitrate of soda may exert a deflocculating action on clay soils, resulting in a condition of toughness and stickiness (A. D. Hall, *J.C.S.*, vol. lxxxv., 1904).

Where potash is not used the sodium contained in this fertilizer appears to possess some value; thus, on the Rothamsted mangold plots the following results are obtained:

MANGOLDS, TONS PER ACRE, 1876–1921.

	Nitrate of Soda.	*Sulphate of Ammonia.*
Superphosphate only	14·9	6·7
Superphosphate and potash ..	15·5	14·0

FERTILIZERS (*Continued*)—

Nitrate of soda further tends to reduce the acidity of the soil slightly. Thus, when nitrate of soda had been added over a period of years the following soil reactions were observed (E. M. Crowther, *J. Agric. Sci.*, vol. xv., 1925).

	Woburn.	*Rothamsted.*
No manure	5·80	5·72
2½ cwts. nitrate of soda	6·28	6·31

Some 94,000 tons of sodium nitrate were made in Germany in 1928 by the ammonia oxidation process. This product differs from the natural nitrate in being free from traces of impurities which may be injurious (perchlorates) or beneficial (iodates). The benefit derived from the iodine content of natural nitrate has been much emphasized, but so far has not been established by experiment.

Nitrate of soda is suited to dry districts, for top-dressing purposes, and particularly for deep-rooting crops such as mangolds, sugar-beet, and wheat. At Rothamsted on the classical fields, and in the presence of complete manures, the effect of nitrate on wheat and on mangolds is 114 and 120 respectively when ammonia nitrogen is put at 100. On barley, a shallow-rooting crop, it is only 95. Nitrate is the preferred form of top dressing for sugar-beet on the Continent, especially in the drier districts. In the Eastern Counties, nitrate of soda up to 3 cwts. per acre has been profitable on this crop (*Norfolk Agric. Stat. Rept.*, No. 7, 1927). At certain centres there is evidence that heavy dressings of nitrate tend to depress the sugar content and produce more leaf than root (*Roth. Rept.*, 1927-28). At many centres in Ireland 1 cwt. of nitrate of soda gave a satisfactory increase in the crop and had value in pushing the plant through insect attacks in the early stages (*J. Dept. Lands and Agric.*, xxviii., 1929). Many trials on mangolds in a range of soils show that nitrate is superior to ammonia for this crop, particularly where no potash is used (*Bd. Agric. Rept. on Manuring of Mangels*, 1909).

Nitrate of soda is used in market-garden practice for forcing leafy vegetables (*Kirton Rept.*, 1927), and the effectiveness of varying amounts of nitrate on a wide range of vegetable crops has been ascertained on a heavy soil in Kent (Dyer and Shivell, "The Manuring of Market Garden Crops," London, 1924).

For potatoes sulphate of ammonia is the usual form of nitrogen, but for early crops it is sometimes recommended that one-third of the nitrogen should be given as nitrate (*Jersey Rept.*, 1927).

POTASH MANURES—The chief source of potash for agricultural purposes is the great saline deposit at Stassfurt in Central Germany. These beds were originally worked for common salt, and the associated veins of sulphates and chlorides of potash and magnesia were formerly regarded as useless. In 1861 the first factory was set up for the concentration

FERTILIZERS (*Continued*)—

of these waste salts for fertiliser and industrial purposes, and they now supply about 75 per cent. of the world's potash requirements.

The composition, grade, and degree of purity of the raw salts vary greatly. Of the large number of substances which occur, Carnallite, $KClMgCl_2.6H_2O$; Sylvinite, $KCl.x.NaCl$; Kainit, $KCl.MgSO_4.3H_2O$; and Kieserite, $MgSO_4.H_2O$ are important. The average potash content of the raw salts is about 12 per cent. The higher grade deposits, 12-14 per cent. or more of potash, are used direct on the land under the name of Kainit, the remainder are concentrated to yield potassium chloride of from 60 to 98 per cent. purity. This product is either (1) used as such for fertilizing purposes, or (2) mixed with raw salts so as to raise the percentage of potash to 20, 30, or 40 per cent.; or (3) converted into potassium sulphate by treatment with Kieserite, an intermediate stage being a manure salt called sulphate of potash-magnesia.

In the French deposits of Alsace the chief mineral is sylvinite. There are no important beds of sulphates, so the potash is turned out as potassium chloride of various grades. In addition to the above main producing areas, similar salts are mined for potash in Poland and in Spain, while in California the brine of Searles Lake, containing 2·5 per cent. K_2O, is worked for high-grade potassium chloride.

The world production of potash (K_2O) in 1927 was as follows:

	Metric Tons.
Germany	1,518,000
France	372,000
Poland	47,000
United States	39,000
Spain	11,000

The composition of the common potash manures is approximately as follows; only the percentage of K_2O is guaranteed, however:

	K_2SO_4.	*KCl.*	*NaCl.*	$MgSO_4$.	*Guaranteed* K_2O.
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Sulphate of potash	89-96	0-4·5	5-4	1·5-4·5	48
Muriate of potash	0-3·5	79·1-85·4	10-16	0-5	50
Potash salts 30 per cent.	0-3	48-51	22-49	0-16	30
Potash salts 20 per cent.	0-3	32-35	39-64	0-16	20
Kainit	0-4	19-24	29-77	0-32	12*

In the plant, potassium is concerned with the formation and translocation of carbohydrates. It is present in largest quantity in buds, growing points, tubers, and other regions of active growth. It assists in the formation of cell-wall, thereby improving the straw of cereals and tends to protect plants against frost. It promotes what gardeners call a " hard " type of growth which is associated with strength, vigour,

* Usually guaranteed 14 per cent. in England.

FERTILIZERS (*Continued*)—

and resistance to fungus and other diseases. This property of potash is finding application among growers. In the glass-house industry the stripe disease of tomatoes is reduced by generous applications of potash. (See Glass-house Crops.) Leaf scorch of gooseberries has been checked on light dry soils (*J. Pom.*, vol. vi., No. 3, 1927), and a dressing of from 2½ to 4 cwts. per acre of sulphate of potash has reduced leaf scorch of apples (*J. Pom.*, vol. vii., No. 1, 1928).

The effects briefly noted above are associated with the potassium as distinct from the other bases and their accompanying acid radicles present in potash salts, the effect of which constituents should not be overlooked. Sodium can partially, but not completely, replace potassium in the plant and can liberate potassium from the exchange complex of the soil (E. J. Russell, *J. Bd. Agric.*, xxii., 393, 1915). Magnesium (if present as sulphate) is sometimes regarded as a useful constituent of potash salts for potato culture, especially if used with farmyard manure (*Landw. Vers. Stat.*, vol. c., p. 315, 1923). It is also of value in soils which are markedly deficient in magnesia. Sulphates have no ill-effect on agricultural crops; chlorides, on the other hand, are distinctly harmful to the quality of potatoes, and tobacco, although the common salt of the low-grade potash salts appears to be favourable to mangolds, sugar-beet, and grassland.

The potash fertilizers in common use are:

Sulphate of potash, 48 per cent. K_2O. Suitable for potatoes, market garden crops, and fruit where quality of produce is the main consideration. The unit price of potash in this form is higher than in the chloride manures.

Muriate of potash, 50 per cent. K_2O. For general purposes and for mixtures made on the farm.

Potash salts, 30 per cent. K_2O. Similar to muriate, but containing about 35 per cent. salt.

Kainit, 20 and 14 per cent. K_2O. Suitable for mangolds, sugar-beet, grassland, and other crops which benefit from common salt. Forms in common use on the Continent, but little known in this country, are manure salts, 40 per cent. K_2O, and sulphate of potash-magnesia, 26 per cent. K_2O.

The use of potash goes hand in hand with intensive farming. Where there is much farmyard manure (which contains about 13 lbs. K_2O per ton) available the need is partly met from this source.

Thus, when the increase in yield due to potash without dung is set at 100, the increase with dung was:

Potatoes (Rothamsted)	36
Sugar-beet (Lauchstädt)	18
Sugar-beet (Dickopshof)	29

Under English conditions the bulk of the potash used is applied to potatoes, sugar-beet, mangolds, and market garden crops. On the light soils, which on the whole give the greatest response to potassic manuring, cereals, clovers, and permanent grass also receive potash.

Recent work has shown that the potash in potato manures is best given as sulphate or muriate of potash, and not as low-grade salts.

FERTILIZERS (*Continued*)—

Thus yields per acre at Rothamsted in 1921-1926 (*Roth. Rept.*, 1925-26) were:

No potash	6·7 tons
Sulphate of potash	8·75 ,,
Muriate	8·82 ,,
Low-grade salts	8·31 ,,

Moreover, it has been shown that, provided sulphate of potash and sulphate of ammonia are used in about equal weights per acre, the amount of sulphate of potash in the potato manure may be increased up to 2 cwts. per acre with advantage. Where conditions are favourable to good growth even 4 cwts. is not too large a quantity.

For sugar-beet from 1 to 2 cwts. of muriate of potash, or its equivalent of 20 or 30 per cent. potash salts, is the usual dressing in this country. There is evidence that the common salt in the lower grade manures is beneficial (*Roth. Repts.*, 1925-1928). Experiments on the Continent show that potash exerts a slightly beneficial effect on the sugar content; thus, Schneidewind summarizes a number of results from German experimental stations:

CHANGE IN SUGAR CONTENT DUE TO POTASH.

Braunschweig	4 experiments	0·2 per cent.
Breslau ..	9 ,,	0·2
Göttingen	2 ,,	0·6
Halle ..	21 ,,	0·3
Königsberg	2 ,,	−0·2
Pentkowo	3 years	0·2
Kikopshof	4 ,,	0·3
Lauchstädt	7 ,,	0·6

The application of sulphate of potash to the barley crop had no great influence on the yield under conditions of good farming, but tends to depress the nitrogen content of the grain and therefore to improve the malting quality, yet not sufficiently to increase the market value (*J. Inst. Brewing*, xxxiv., 307, 1928). On the other hand, the clover following barley so treated was markedly benefited (*J.R.A.S.E.*, p. 134, 1928). Potash salts increase the yield of hay, from permanent grass on the lighter soils, and improve the effects of phosphates for grazing purposes on such land, but not as a rule on typical heavy land grazings (*Min. Agric. and Fish.*, Misc. Pub., No. 30).

(For the effect of potash on fruit trees see Fruit Trees, Manuring of, under Fruit.)

GENERAL REFERENCES.—O. Nolte, "Die Bedeutung des Kalis," Berlin, 1927. Technical: Herman, "Einfuhrung in die Kali Industrie," Halle, 1921. Potash from wastes, etc.: Turrentine, "Potash," New York, 1926.

POULTRY MANURE—This substance is becoming increasingly important in view of the large number of head of poultry now being kept. It is estimated that 1,000 fowls will produce about 1 cwt. of manure per day in the houses and a similar amount outside. Like other

FERTILIZERS (*Continued*)—

manures, the composition of poultry manure depends on the feeding, but the amount of moisture and earthy matter present will, of course, produce the greatest effect on the value per ton. Typical analyses are:

	*Birds at Liberty.**		*Fattening Birds.**		*Good Sample stored under Cover.*†	*Mixed with Litter (Chaff).*†
	Fresh.	*Air Dry.*	*Fresh.*	*Air Dry.*		
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Dry matter ..	40·5	90·0	29·7	85·0	77·59	90·57
Nitrogen ..	1·75	4·0	2·28	6·52	5·03	2·12
Phosphoric acid	1·00	2·27	0·97	2·77	3·62	0·97
Potash ..	0·54	1·22	0·55	1·57	2·03	—

Poultry manure may range, therefore, from a high grade organic nitrogenous manure to a comparatively moist, unsowable material, according to the care taken in handling it. The aim should be to reduce it to a fine, dry powder without undue loss of ammonia by fermentation. Storage with alternate layers of dry earth in a shed is good practice, but wood ashes, lime, or other alkaline material should not be used for this purpose, otherwise ammonia will be lost. Since poultry manure is much richer in nitrogen than in the other constituents, it is best used in conjunction with phosphatic and potassic fertilizers. Where poultry manure is produced in quantity some mechanical treatment is the best course. Thus in Philadelphia feeding stations the manure is steam-dried, ground, and bagged up. The final product contains 6½ per cent. nitrogen, 3 to 4 per cent. phosphoric acid, and 1 to 2 per cent. potash (*Amer. Fert.*, p. 48, 1927). This procedure is nevertheless quite exceptional.

ROCK PHOSPHATES—These occur in enormous quantities as beds of tricalcic phosphate containing varying amounts of carbonates of lime and magnesia, oxides of iron and aluminium, and frequently calcium fluoride. In those deposits which are extensively worked, the content of calcium phosphate ranges from 55 to 85 per cent. Generally speaking the hardness of the rock and its resistance to dilute acid solvents increase with the amount of phosphate present.

The mining of phosphate rock is a considerable industry. In 1927 the following quantities were produced in the chief mining areas:

	Metric Tons.
North Africa (chiefly Tunis, Morocco, Algeria) ..	5,225,000
United States (chiefly Florida and Tennessee) ..	3,301,000
Ocean and Nauru Islands, etc.	690,000

* Brown, *J. Bd. Agric.*, xiii., 1907.
† Voelcker, *J.R.A.S.E.*, vols. lxxvi. and lxxxiv., 1915 and 1923.

FERTILIZERS (*Continued*)—

It is estimated that 80 per cent. of this output is used in the manufacture of superphosphate, the bulk of the remainder being finely ground and then applied to the land. Interest at present lies in determining the extent to which the raw ground rock phosphate may be used economically.

That the application of mineral phosphate results in crop increases has been shown by many investigators. Probably the most extensive survey of the results obtained in arable experiments was made by Waggaman in the United States, where its effectiveness was on the whole beyond question (*U.S. Dept. Agric. Bull.*, No. 699, 1918).

All investigators agree that the enormous increase in surface produced by fine grinding is an important factor in the availability of rock phosphates. Jamieson (*Aberdeen Agric. Assoc. Rept.*, 1881), and also Aitken (*Trans. H. Agric. Soc.*, 1886 and 1887), working with these substances in Scotland in the early eighties, showed that, if finely ground, mineral phosphate had an effect on arable crops very little inferior to superphosphate. The value of fine grinding was also observed by Gilchrist (*J. Min. Agric.*, vol. 29, 1922).

Rock phosphates are now obtainable ground so that 80-90 per cent. passes a 120-mesh sieve, which is equivalent to 90 per cent. or more through the 100-mesh sieve used for basic slag. The finer grinding is recommended. On the Continent rock phosphate has been ground to a very much finer state of division to give the so-called colloid phosphate, but investigators are not agreed as to whether this is necessary (*Zeitschrift für Pflanzenernährung und Düngung*, iv., B, pp. 11-24, 1925).

The type of rock is also important; most experimental results tend to show that of the phosphates which have received most attention in this country the softer type from N. Africa represented by Gafsa phosphate has been, on the whole, more effective than the richer but harder class such as the Florida or the Nauru (Robertson, *J. Min. Agric.*, vol. xxix., 1922).

On the whole, the districts where ground rock phosphates have succeeded best are those of medium to high rainfall (*University Coll., N. Wales, Bangor, Bull.*, 1925). In very dry regions they have not done so well (*Leeds University, Bull.* 162, 1909). Robertson, however, has shown that on certain soils in Essex they still exert a good effect (Robertson, *loc. cit.*).

As far as the soil is concerned acidity is usually assumed to favour the action of rock phosphate. Excess of chalk in the soil tends to lower the solubility. In Germany ground rock phosphates must be sold with a statement that they are only suitable for use on "hochmoor" soils—acid peats. Robertson found that ground mineral phosphate was no more effective on peaty soils than on mineral soils in Ireland (*J. Min. Agric. Northern Ireland*, vol. i., 1927).

As carbon dioxide in solution has slight solvent properties on soil minerals, conditions which favour the accumulation of carbon dioxide, such as abundant organic matter and brisk bacterial activity, also

FERTILIZERS (*Continued*)—

react favourably on the solution of mineral phosphate. Continental investigators claim that the use of mineral phosphate in combination with physiologically acid manures such as sulphate of ammonia is an advantage.

The crop itself is also a factor in determining the degree of solubility. Russian workers have shown that lupins, buckwheat, and peas have a greater power than the cereals of assimilating insoluble phosphates. Robertson found that turnips were better able to derive their phosphate from the insoluble phosphates than potatoes.

There is, finally, the growing period of the crop, and as rock phosphates are most successful with perennial crops they have been used most extensively in this country for long leys and permanent grass. There is much evidence to show that if a result is not obtained on grassland in the first year—which only happens when conditions are favourable—a benefit is usually apparent in the second or third seasons.

It is seldom that ground rock phosphate will give results actually better than superphosphate or high soluble basic slag (there are many cases on record where it has acted better than fluorspar basic slags), but in view of its relatively low price per unit of phosphoric acid rock phosphate may frequently be the most economical form of phosphatic manure to employ.

General References.—Waggaman and Easterwood, "Phosphoric Acid, Phosphates and Phosphatic Fertilizers," New York, 1927; Collins, "Chemical Fertilizers," London, 1920.

SEWAGE SLUDGE—The enormous potential fertilizing value of sewage has so far not been realized. The process of purification causes most of the soluble constituents to pass away in solution, while the solid residue settled out or filtered off as sludge usually contains but small amounts of plant food of very low availability. The sludges also contain from 50 to 90 per cent. of water according to conditions, and can therefore only be used in the immediate vicinity of the sewage works; in most cases their disposal is a definite cost to the community. Several types of sludge exist, however, whose fertilizing values are quite distinct: (1) Anaerobic sludge, settled out in absence of air in septic tanks or precipitation tanks, containing on the average 1·22 per cent. nitrogen on the dry matter. Such sludges have been shown to have very little fertilizing value either on roots or grass, but the lime which is added, in some cases, slightly improves their performance (Appendix to 5th Report Sewage Commission, Cd. 4286, 1905). The removal of grease, which may be economic on technical grounds, does not appear to increase their manurial value (Appendix to 9th Report Sewage Commission, Cd. 7819, 1915). This type of sludge is only of use when it can be obtained, free of cost, in the immediate neighbourhood of sewage works. (2) Aerobic sludge. Recently a system of purification involving the forced passage of air through the sewage has been introduced. The resulting "activated" sludge has been

FERTILIZERS (*Continued*)—

shown to possess greater manurial value than anaerobic sludge, as the following analyses indicate:

PERCENTAGE OF DRY MATTER.

	Nitrogen.	*Phosphoric Acid.*	*Potash.*
Precipitation sludge (anaerobic) ..	0·89	0·66	0·07
Slate bed (partially anaerobic) ..	2·63	0·34	0·08
Activated sludge (English) ..	7·04	3·82	1·12
Activated sludge (American) ..	5·60	3·40	0·50

The activated sludges not only contain a much higher percentage of nutrients, but the nitrogen is in a form capable of ready nitrification. Both in this country (*J. Soc. Chem. Ind.*, vol. xxxix., p. 177T, 1920; *ibid.*, vol. xli., p. 62T, 1922) and in the United States (Noer, *J. Amer. Soc. Agron.*, 1926) they have been shown to possess valuable manurial properties. The chief difficulty with activated sludge is the removal of the 98 per cent. of water which the original sewage contains. This has been successfully accomplished at Milwaukee, U.S.A., where an output of 70 tons dried sludge is readily disposed of to farmers.

Ordinary sewage sludges are occasionally dried and ground in this country, when they fall into the class of low-grade organic manures of somewhat low availability, and may be bought on analysis. The nitrogen should not be valued as highly as in mineral fertilizers or in active organic manures such as fish meal and guano.

SOOT—The agricultural value of soot was recognized in early times, and it was consequently one of the commonest fertilizers before the introduction of artificial manures. Its value is associated with its content of ammonium salts, the nitrogen ranging from practically nothing up to 7 per cent., according to the origin of the sample. Domestic soot, from open fires, is the richest, next in order of value comes the soot from stoves and closed ranges; whilst the poorest is obtained from factory chimneys (*J. Soc. Chem. Ind.*, xxx., 1361, 1911.) The following are typical analyses:

	Coal.	*Living-room Soot.*	*Kitchen Soot.*	*Factory Soot.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Nitrogen ..	1·72	6·0	4·1	1·2
Ash	1·80	5·1	17·8	66·0

The weight per bushel is a rough guide to nitrogen content. In a good sample it should be not more than about 24 lbs. The following figures relate to two types of soot:

FERTILIZERS (*Continued*)—

	Nitrogen (per Cent.)	*Weight (Lbs. per Bush.).*	*Nitrogen (Lbs. per Bush.).*
Domestic	4·87	21·9	1·01
Factory	0·96	41·7	0·37

Apart from its value as a source of readily available nitrogen, soot has certain secondary effects; it contains a complex mixture of hydrocarbons and sulphur compounds which are injurious to slugs and soil insects, and the dark colour imparted to the soil facilitates the absorption of the sun's rays.

SULPHATE OF AMMONIA—This is the most important nitrogenous fertilizer from the point of view of tonnage, both in Great Britain and elsewhere. Approximately 42 per cent. of the world production of combined nitrogen in 1927-28 was in the form of sulphate of ammonia, about one-half of this coming from gas works and coke ovens, the remainder being made from atmospheric nitrogen. By-product sulphate of ammonia is mainly derived from coal, which is distilled on a very large scale for the production of illuminating gas, or the preparation of coke for smelting purposes. The nitrogen of the coal is evolved as ammonia and absorbed in water. It is then driven off by lime, and finally neutralized with sulphuric acid to give crystalline ammonium sulphate. Of the 0·5-2 per cent. of nitrogen contained in the coal about one-sixth is recovered in the form of ammonium sulphate on distillation. In Scotland a considerable amount of sulphate of ammonium is similarly made by the distillation of oil-bearing shales.

In recent years an increasing amount of ammonium sulphate has been produced by the synthetic ammonia process at Billingham-on-Tees, Co. Durham. This process was worked out in Germany by Professor Haber just before the Great War, and has since then made enormous strides. It consists of the combination of hydrogen and nitrogen to form ammonia, the action proceeding at a pressure of 200 atmospheres and a temperature of 500° C., in the presence of a catalyst. The necessary hydrogen is derived from water-gas. The ammonia thus formed is either neutralized by sulphuric acid or caused to react with gypsum, $CaSO_4$, in presence of carbon dioxide. In either case sulphate of ammonia is formed, in the latter case chalk is a by-product. The gypsum process is used at Billingham.

In 1927 the home production of sulphate of ammonia was 471,000 tons, of which 252,000 tons were exported and 168,000 tons were used by British farmers. An increasing proportion of the home output is synthetic. Until recently ordinary sulphate of ammonia contained 20 per cent. nitrogen; there was also a little free sulphuric acid which caused the bags in which the manure is usually transported to rot on storage.

FERTILIZERS (*Continued*)—

The greater part of the sulphate of ammonia produced in this country is now of the so-called neutral quality, and is guaranteed to contain 20·6 per cent. nitrogen and less than 0·025 per cent. free acid. When sulphate of ammonia is added to the soil the ammonia is absorbed by the soil colloids, *i.e.*, clay and humus complexes, and is thus protected from leaching. An equivalent amount of calcium passes into the drainage water as calcium sulphate. In this way the soil loses calcium, and if ammonium salts are used for a period of years, soil acidity will sooner or later become noticeable unless there is an excess of chalk present. The retention of ammonia is not permanent, for under favourable conditions it is converted into nitrate by the soil micro-organisms, and is then either taken up by the crop or washed out of the surface soil. (See Lysimeter).

Nitrification proceeds best when the soil is moist and warm, well aerated, and is not acid. Although ammonia is transformed into nitrate most readily in presence of chalk, a certain amount of nitrate is still formed under acid conditions (J. Hendrick, *Fert. and Feed. Stuffs J.*, No. 14, 1929). It has been shown that agricultural crops can utilize ammonia nitrogen (Hutchinson and Miller, *J. Agric. Sci.*, vol. iii., 1909). Some of them, such as peas, barley, oats, can utilize ammonia or nitrate equally well, wheat and mangolds prefer nitrate, while potatoes are said to prefer ammonia nitrogen (Krüger, *Landw. Jarb.*, No. 34, 1905), although this is rather exceptional. Under ordinary soil conditions nitrate is the usual form in which crops take up their nitrogen, and conditions should in general be made as favourable as possible for nitrification, by drainage, cultivation, and provision of chalk, where necessary. The acidifying effect of sulphate of ammonia when used over long periods on soil poor in lime has been brought out by the continuous experiments on hay at Rothamsted and on barley at Woburn (E. M. Crowther, *J. Agric. Sci.*, vol. xv., 1925). The good effect of periodical dressings of lime in correcting the acidity is also shown:

WOBURN, CONTINUOUS BARLEY, FORTY-SIXTH YEAR.

Yearly Manuring.	*pH.*
No manure	5·83
Sulphate of ammonia, 20 lbs. nitrogen	4·46
Sulphate of ammonia + 2 tons lime, 1897 and 1912	6·46

ROTHAMSTED, CONTINUOUS HAY, SEVENTY-EIGHTH YEAR.

Yearly Manuring.	*pH.*
No manure	5·72
Sulphate of ammonia, 46 lbs. nitrogen	4·84
Sulphate of ammonia + 2,000 lbs. lime, 1903, and at four-yearly intervals	6·54

If sulphate of ammonia is applied to calcareous soils and left exposed on the surface, a loss of ammonia may take place. Thus, it has been observed that the atmosphere is unusually rich in ammonia following the application of ammonium salts to the Broadbalk field

FERTILIZERS (*Continued*)—

at Rothamsted (Miller, *J. Agric. Sci.*, vol. iv., 1911). The inferiority of sulphate of ammonia to nitrate of soda on alkaline soils has been attributed to the same cause (Prescott, *J. Agric. Sci.*, vol. xiii., 1923). In recent years sulphate of ammonia has been the subject of exact trials on a number of farm crops over a range of soils. In presence of sufficient phosphoric acid and potash it usually gives very certain crop increases, the average increase per 1 cwt. of sulphate of ammonia used being:

Wheat	4½	bushels
Barley	6	,,
Oats	8	,,
Potatoes	20	cwts.
Mangolds	32	,,
Hay	9	,,

For winter cereals it is best applied as a top-dressing in spring. The time of application has recently been studied at Rothamsted and elsewhere. If a large dressing is given (say, 2 cwts. per acre) it is best applied early in the spring when tillering is active, when it increases both the grain and the straw. If a smaller dose is given (1 cwt. per acre), the best results appear to be obtained by withholding the application until later in the season, when the tillers which are already formed are caused to produce grain, but the straw is not increased to the same extent (*Roth. Rept.*, 1927-28).

In the case of barley it has been shown that a moderate application of sulphate of ammonia (1 cwt. per acre) is the most effective constituent of a complete fertilizer mixture for increasing the yield. The average yield increase obtained at Rothamsted in the years 1923-25 was 6½ bushels. One hundredweight of sulphate of ammonia also has no ill-effect on the quality of the grain, as measured by the content of total nitrogen, in years when a good yield increase is obtained, always provided that phosphates and potash are also present in sufficient quantity. The double dressing, however, markedly increases the total nitrogen percentage in the grain. On the whole, growers are justified in using 1 cwt. per acre sulphate of ammonia in their barley manuring if they think the crop will stand up at harvest time (*Dept. Agric. T. I. I.*, Leaflet No. 36, 1903, 1904, 1905, 1907; E. J. Russell, *J. Inst. Brewing*, vol. xxxiv., 1928).

Sulphate of ammonia is the most usual source of nitrogen for potatoes, which also require suitable proportions of superphosphate and sulphate or muriate of potash. Experiments indicate that the usual formula for potatoes, viz., 1 cwt. of sulphate of ammonia, 1 cwt. sulphate of potash, and 4 cwts. of superphosphate, may safely be doubled as far as the sulphate of ammonia is concerned, provided that the sulphate of potash is also doubled. The relative effectiveness of nitrogen and potash varies with the season (*J. Dept. Agric. T. I. I.*, vol. xvi., 1916).

For sugar-beet Continental investigators prefer to apply sulphate of ammonia in the seed bed rather than for top-dressing purposes. The results of a series of experiments at eighty centres in 1927 showed

FERTILIZERS (*Continued*)—

that in general an increase in sugar per acre was obtained with dressings up to 3 cwts. per acre (*Min. Agric.*, Misc. Pub., No. 63). On good fenland sulphate of ammonia at seeding time had no effect, also where land was in exceptionally good condition sulphate of ammonia was not required in full quantity. In the west of England the heavier soils were more responsive to sulphate of ammonia than the lighter ones. Nitrogen tends to produce leaf in excess of root and also tends to depress the sugar content when heavy dressings are used. (See Sugar-Beet.)

The use of sulphate of ammonia for grassland improvement was hitherto confined to spring top-dressing to increase the bulk of hay, and this practice was only common on farms run at a rather high level. Recently attention has turned to the question of the utilization of cheap inorganic nitrogen on pasture land, with special precaution for realizing the herbage at an early stage of growth. There is no doubt that with rotational grazing and successive applications of sulphate of ammonia (in presence of lime and the other fertilizers) the production of pastures can be greatly increased and their period of growth prolonged (A. D. Hall, *J. Min. Agric.*, No. 35, 1928; Griffith, *Welsh J. Agric.*, No. 5, 1929; J. Brunton, *J. Farmers' Club*, 1928).

SUPERPHOSPHATE—The idea of increasing the availability of the calcium phosphate contained in bones by treatment with sulphuric acid was due to Leibig. The establishment of the superphosphate industry and the substitution of mineral phosphate for bone phosphate was the work of J. B. Lawes. From 1837 to 1841 Lawes conducted pot and field experiments at Rothamsted in which the value of the acid treatment of calcium phosphate was demonstrated. In 1842 he took out his patent for the manufacture of superphosphate from phosphatic minerals, and the first factory was opened at Deptford in the following year. The world production of superphosphate in 1927 was 14 million tons, of which half a million tons was made in this country.

The manufacture of superphosphate consists essentially in the conversion of the insoluble tricalcic phosphate, $Ca_3(PO_4)_2$, of phosphatic minerals into water-soluble monocalcic phosphate, $CaH_4(PO_4)_2$, by means of sulphuric acid; the excess of calcium combining with the acid to form gypsum, $CaSO_4 2H_2O$. Superphosphate contains from 14 to 16 per cent. of water-soluble phosphoric acid, chiefly as monocalcic phosphate, with a little free phosphoric acid; from 1 to 2 per cent. of phosphoric acid which is derived from unattacked phosphate rock and is insoluble in water; phosphates of iron and aluminium, and a little dicalcium phosphate. There is also about 50 per cent. of gypsum.

Of these constituents the only one to which definite agricultural value is attached is the water-soluble phosphoric acid, the percentage of which must be declared on sale. (See Fertilisers and Feeding Stuffs Act.) The fertilizing value of the gypsum is small, although in the middle of the nineteenth century gypsum was used as a fertilizer, particularly for leguminous crops. Its action depended on the liberation of potash from the soil reserves, and was therefore uncertain,

FERTILIZERS (*Continued*)—

as all soils are not rich in replaceable potash. In any case a realization of soil capital is involved and not fertilization in the strict sense of the word. With the introduction of cheap supplies of potash salts the use of gypsum has been abandoned.

When superphosphate is applied to soil containing a sufficient supply of chalk, the water-soluble phosphoric acid is precipitated in the surface soil as dicalcium phosphate, $CaHPO_4$, and no doubt ultimately the tricalcium salt is formed. Of these two compounds the first is readily soluble in the soil water, the second less so. The rapid effect of superphosphate is due to the solution of these two substances in the soil water, a process aided by their very perfect distribution and fineness of division. On soils poor in calcium and rich in iron and aluminium the water-soluble phosphoric acid is precipitated largely as highly insoluble iron and aluminium phosphates, and in this condition the phosphate is less available to plants than as the corresponding calcium compounds. Hence the correction of soil acidity assists in realizing the full value of water-soluble phosphate.

The view widely held that superphosphate tends to make the soil acid has been disapproved. When the hydrogen ion concentration (pH) of the soil from plots receiving repeated applications of superphosphate is compared with that of untreated plots no appreciable increase in pH is observed.

Thus in the Park Grass plots on the heavy loam at Rothamsted, (*J. Agric. Sci.*, vol. xv., 1925), which have received their manures yearly since 1856, the following soil reactions have been determined:

pH.

	Unlimed.	*Limed.*
No manure	5·72	6·88
3½ cwts. superphosphate	5·69	7·12

On the continuous barley plots on the light soil at Woburn conducted on similar lines since 1874, the figures were:

pH.

Unmanured	5·80
Minerals	5·80
Nitrate of soda	6·14
Nitrate + minerals*	5·81
Sulphate of ammonia	4·46
Sulphate + minerals	4·68

The rapidity of action of superphosphate enables it to be used with confidence as a seed-bed application or even as a top-dressing in case of need. It is especially useful for crops such as the cereals and potatoes, which have a very limited power of utilizing the more insoluble mineral

* 3 cwts. superphosphate and ½ cwt. sulphate of potash per acre.

FERTILIZERS (*Continued*)—

phosphates. Robertson, for instance, at a series of centres in Northern Ireland, in 1924 (*J. Min. Agric. N. I.*, vol. i., 1927), obtained the following results:

	Potatoes (*Tons per Acre*).		*Turnips* (*Tons per Acre*).
	No Dung.	Dung.	No Dung.
No phosphate	4·8	7·8	2·2
Superphosphate	11·9	11·0	18·9
Gafsa phosphate	7·8	9·5	16·1

Thus, although the potato crop utilized the water-soluble phosphate much better than the rock phosphate, it was found that the turnip crop was able to draw on both types of phosphate almost equally.

Superphosphate is also valuable for those crops where an early start is essential, either to establish them before the onset of winter, or to help them through a period of drought. This action of hastening growth may be a disadvantage where excessive quantities of superphosphate are used and a dry ripening season is encountered. Cases are on record where barley and potatoes are believed to have suffered loss of yield in this way, the crops having matured before full growth had been accomplished.

The proportions of superphosphate in artificial mixtures for use on potatoes has been studied by Wallace at Kirton, who finds that on silt soils there is a tendency among growers to use unduly heavy applications of superphosphate. These experiments are being followed up on other soils throughout the country (*Roth. Sta. Rept.*, 1927-28).

Experiments at a number of centres have shown that superphosphate produced on the whole no very marked effect on the yield or quality of malting barley, although the effect in certain seasons was good. (See Barley.) Probably in well-farmed districts enough phosphate is applied to the root crop to meet the needs of the succeeding barley crop (*J. Inst. Brewing*, xxxi., 1925; xxxiv., 1928). In the eastern counties, however, superphosphate increased the yield of barley, and brought the grain evenly and rapidly to harvest (*J.R.A.S.E.*, vol. lxxxviii., 1927). German investigators find that superphosphate has little influence in the sugar content of beet except in late seasons, but its valuable influence in establishing the young plant is recognized (Schneidewind, *Die Ernährung der Ländwirtschaftlichen Kulturpflanzen*, Berlin, 1928).

The use of superphosphate for pasture improvement has been overshadowed by the success of basic slag in this sphere, the latter being slightly cheaper per unit of phosphoric acid and also containing more available calcium. In dry, chalky, or limestone areas, however, superphosphate does well, and in most districts superphosphate and lime have been quite successful. In the Dominions and the United

FERTILIZERS (*Continued*)—

States, however, superphosphate is the main agent for pasture improvement, and occupies the same position there as basic slag does in this country. On certain soils which are so deficient in phosphoric acid that the grazing stock do not get enough phosphorus for their needs, the application of superphosphate increases the phosphoric acid content of the herbage, thereby promoting the growth and thriftiness of the animals (J. B. Orr, "Minerals in Pasture," London, 1929).

TOWN REFUSE—The ashpit refuse of towns is produced in enormous quantities. The gross annual production in England and Wales is about 12 million tons and the cost of disposal about £8,000,000.

When the tins, bottles, cinders, etc., are removed a coarse powder is left which is used in the neighbourhood of towns as a fertilizer. The composition is extremely variable, but it usually contains:

Organic matter	25·0-40·0 per cent.
Nitrogen	0·4- 0·6 ,, ,,
Phosphoric acid	0·3- 0·5 ,, ,,
Potash	0·3- 0·5 ,, ,,

Its chief value is its physical effect in lightening heavy soils, but it also has a slight manurial action principally associated with its nitrogen content. The nitrogen is also bound up with the content of easily decomposable animal and vegetable matter, hence winter consignments are not as rich as summer deliveries on account of the higher proportion of coal ashes present. It is usually assigned a cash value of about half that of town stable manure (E. J. Russell, *J. Min. Agric.*, xxix., 1922). There have been few experiments reported with town refuse, but the following are on record (*Roth. Rept.*, 1923-24; *Cockle Park, Bull.*, No. 34, 1922):

	Rothamsted.		*Cockle Park.*
	Mangolds.	*Oats.*	*Swedes.*
	Tons.	Bushels.	Tons.
No manure	9·6	25·0	—
15 tons dung	13·2	—	25·4
15 ,, ordinary refuse A	14·0	—	—
15 ,, ,, ,, B	13·9	—	—
15 ,, enriched refuse C	—	—	22·1
5 ,, ordinary refuse D	—	27·1	—
10 ,, ,, ,, D	—	30·6	—

When town refuse is enriched by additions of considerable quantities of street sweepings, night soil, stable manure, or slaughter-house waste, material of much higher fertilizing value is obtained, in which the nitrogen ranges from 1 to 2 per cent.

FERTILIZERS (*Continued*)—

UREA ($CO(NH_2)_2$)—This substance, which is the most valuable fertilizing constituent of the urine of live stock, contains no less than 46 per cent. of nitrogen of high availability. It is prepared artificially by the interaction of synthetic ammonia and carbon dioxide or by the hydrolysis of cyanamide, and finds considerable use on the Continent as a constituent of high-grade fertilizers, chiefly for horticultural purposes. When applied to the land it is transformed into ammonia, and finally reaches the nitrate form. Unlike salts of ammonia it leaves no acid residue in the soil. Urea has been compared with other nitrogenous fertilizers (*Roth. Rept.*, 1925-26; 1927-28).

On the basis of sulphate of ammonia =100, the effectiveness of urea has been:

Rothamsted: Barley, 4 comparisons	104
,, Oats, 1 comparison	109
,, Swedes, 2 comparisons	100
Woburn: Potatoes, 2 comparisons	103

It is therefore of about the same degree of effectiveness as sulphate of ammonia.

MISCELLANEOUS—Dried Blood—This is a very active nitrogenous manure, the nitrogen being nitrified at a rate comparable with that of ammonium salts. It is in such demand for feeding that its fertilizer price is high; consequently it is almost confined to horticultural and glasshouse crops. Dried blood usually contains about 12 per cent. of nitrogen.

Fish Manures—Waste fish and fish residues are used to a certain extent in coastal districts for manurial purposes, and provide fairly readily available nitrogen. The bones being unground take some time to produce any effect. Good results have been obtained on sugar-beet and on mangolds. There is an extensive trade in the residue obtained after the oil extraction of ground dried fish. The good grades are used under the name of fish meal for feeding, the coarser grades for manure (fish guano). Fish guano is very similar to meat guano (*q.v.*) in its action. It also has a similar range of application. A usual analysis is 8-10 per cent. nitrogen, and 4·5-9 per cent. phosphoric acid.

Hoof and Horn—This material is used extensively in horticultural and market garden practice as a steady source of nitrogen. The raw materials are gently roasted or steamed to facilitate grinding and to increase their availability. The meal contains from 12 to 14 per cent. of nitrogen, and should be finely ground. If the bone is also present the nitrogen content falls and a corresponding percentage of phosphoric acid is introduced. The nitrogen is present in a fairly active condition, lying between that of dried blood and fish guano in availability.

Leather Waste—This is produced by roasting or steaming scrap leather, and finally grinding it to powder. It contains about 7 per cent. of nitrogen in an exceedingly unavailable form. Treatment

FERTILIZERS (*Continued*)—

with sulphuric acid makes some improvement, but in any case this substance has very little value as manure (*J.R.A.S.E.*, p. 427, 1919; *J. Min. Agric.*, vol. xxi., p. 1091, 1925). The small scraps of untanned leather from glove factories are used in their natural state to some extent in market garden practice.

Meat Meal—(Meat Guano)—This consists of the waste flesh from slaughter-houses after the fat has been removed by heat and pressure, and the residue finely ground. It always contains a certain amount of bone. The purer grades find their most profitable outlet as a feeding stuff, the remainder finds a ready sale as an organic manure containing nitrogen and phosphoric acid. The composition varies greatly. Pure flesh contains 16 per cent. of nitrogen, but a high-grade meat meal would contain 8-9 per cent. of nitrogen and 5-7 per cent. of phosphoric acid, while samples containing more bone should have about 4-5 per cent. of nitrogen and 16-18 per cent. phosphoric acid.

The nitrogen of this waste product is readily nitrified, and the phosphate may be compared with bone meal of the same degree of fineness of division. Meat meal finds its best use for horticultural and market garden crops, and for fruit.

Rape Cake—This residue from the manufacture of rape oil was formerly widely used as a nitrogenous manure. It was the source of organic nitrogen used in the Rothamsted experiments, and its performance has been more exactly measured than that of any other organic manure (A. D. Hall, "Book of the Rothamsted Experiments"; E. J. Russell, *J. Min. Agric. and Fish.*, vol. xxvi., p. 228, 1919). Recently it has been largely displaced by the much cheaper inorganic nitrogen compounds. It contains about 4-5 per cent. nitrogen, 2 per cent. phosphoric acid, and 1 per cent. potash. Most of the effect of the nitrogen is exerted in the year of application.

Seaweed—This is highly prized in coastal districts as a manure. Different species of weed differ in fertilizing value. *Laminaria* sp. (driftweed or tangle) grow below low-water mark, and are either washed ashore or cut and collected from boats. *Fucus* sp. (cut weed, bladder wrack) grow between tide marks and are more readily obtained. The former species have the better analysis. (See G. H. Pethybridge, "Cultivation of Seaweed in Ireland," *J. Dept. Agric. and Tech. Instruc.*, April, 1915.)

Seaweed provides organic matter, potash, a little nitrogen (0·33 per cent.), and extremely little phosphoric acid (0·1 per cent.). The most valuable constituent is potash, of which the average amounts are:

	Laminaria. Per Cent.	*Fucus.* Per Cent.
In wet weed	1·28 to 1·83	0·78 to 1·02
In dry matter	5·25 ,, 10·49	2·52 ,, 4·18
In ash	20·2 ,, 33·6	12·2 ,, 18·6

Seaweed has certain points of similarity to dung. It is only slightly poorer in nitrogen, much poorer in phosphoric acid, but considerably

FERTILIZERS (*Continued*)—
richer in potash. The nitrogen and potash are fairly readily available, but for most purposes additional phosphate should be supplied. When readily obtainable, seaweed is used for potatoes in much the same quantity as dung, but is usually supplemented with artificials (*Trans. H. Agric. Soc.*, p. 118, 1898).

Shoddy—This consists of the wool waste from the Yorkshire mills which is too short to be worked up again into cloth in the machines. Pure wool contains 17 per cent. nitrogen. Shoddy, owing to the presence of varying amounts of grit, cotton, oil and water, never reaches this figure. A high-grade shoddy waste would contain 12-14, ordinary grade 5-8, and low grade 3 per cent. of nitrogen. The nitrogen compounds decompose slowly but steadily in the soil. Applied at the rate of 1 ton per acre at Rothamsted, shoddy showed a distinct residual effect, but this was less certain when the dressing was 9 cwts. per acre. The nitrogen in shoddy waste is not quite as active as that of rape cake or guano, nevertheless its chief effect appears in the first crop (*J. Min. Agric.*, vol. xxi., p. 1087, 1915; vol. xxvi., p. 425, 1919). Shoddy should always be bought on analysis, as its composition is very variable. It should be in a fairly well divided condition, and is best ploughed into the land some time before growth commences.

FERTILISERS AND FEEDING STUFFS ACT, 1926, THE—The need for legislation to control the trade in fertilisers and feeding stuffs has arisen only within comparatively recent years. It was not until towards the middle of the nineteenth century that artificial fertilizers, other than some few organic substances, such as bones, began to come into general use; and at about the same time there was taking place in British agriculture the movement from arable farming to live stock and milk production, which resulted in a large and increasing demand for concentrated feeding stuffs.

The two new raw materials of agriculture—chemical fertilizers and concentrated cattle foods—presented a fresh problem to the farming industry, for their value depended upon their chemical composition and could not be judged merely by inspection. The earliest organized assistance which farmers received in testing their supplies was given by agricultural associations: in England, by the Royal Agricultural Society in particular, and in Scotland, by the Highland and Agricultural Society. There can be no doubt that, for a number of years previous to the passage into law of the first British Fertilizers and Feeding Stuffs Act, a good deal of misrepresentation took place, to the detriment of both the farmer and the honest trader.

It was the widespread dissatisfaction with the conditions then existing which led to the appointment, in 1892, of a Departmental Committee to inquire into the complaints made regarding the adulteration of fertilizers and feeding stuffs. The Committee had before them a large mass of evidence, including particulars of the provisions lately made in some European countries and in certain of the North

FERTILISERS AND FEEDING STUFFS ACT, 1926, THE (*Continued*)—
American States, to deal with the same evil. Upon the report of this Committee the Fertilisers and Feeding Stuffs Act of 1893 was based. This Act required sellers of artificial fertilisers, in quantities exceeding ½ cwt., to give a warranty as to the minimum percentage content of nitrogen, soluble and insoluble phosphates, and potash. No percentage figures were required in connection with the sale of feeding stuffs, but it was necessary to state whether the article was prepared from one, or more than one, substance or seed. Samples could be taken for the purpose of checking these statements at any time within ten days of delivery or of receipt of the invoice, whichever was the later. Where the warranty was not fulfilled, the seller was, of course, liable to a civil claim; but he was also open to prosecution for giving a false invoice.

As a result of a few years' experience, certain defects were found in this Act, two of which, it was thought, seriously reduced its value. In the first place, it had been anticipated that farmers would themselves be prepared to take samples for submission to the official analyst, and no direct power was given to local authorities to appoint official samplers. Secondly, some sellers had evaded the law by stating unduly low figures and informing their customers that the article would be found to be much better than the statutory invoice showed.

These points were met in the Fertilisers and Feeding Stuffs Act of 1906, which replaced the earlier Act; and, at the same time, the principle of requiring a warranty as to the percentages of certain valuable ingredients was extended to feeding stuffs.

The Act of 1906 was, however, the subject of much criticism, and in 1923 a further Departmental Committee was set up to inquire into its working. The Report of the Committee, presented in 1924 (Cmd. 2125), showed that several causes had contributed towards the general dissatisfaction with the Act. In particular, farmers objected to the possibility of criminal proceedings being based upon the results of analysing samples which they had had drawn for purely civil purposes, and consequently only a few samples were taken in many districts. Traders, on the other hand, protested that it was unreasonable that they should be prosecuted on the evidence of samples taken from parcels which had passed out of their control several days previously, and which might have been damaged, or even changed, since delivery.

The most important recommendations, therefore, which the Departmental Committee made were:

(i.) That samples taken on the purchaser's premises should be used for civil purposes only; and

(ii.) That samples which were to be used for criminal proceedings should be taken on the premises of the person to be prosecuted.

Both of these principles are incorporated in the Act of 1926. Their effect is to separate civil from criminal proceedings.

The civil provisions of the Act are, briefly, that upon the sale of

FERTILISERS AND FEEDING STUFFS ACT, 1926, THE (*Continued*)—
certain specified fertilisers and feeding stuffs—including all the artificial fertilisers and concentrated cattle foods in ordinary use—the purchaser is entitled to a " statutory statement " showing the name of the article and the percentage content of prescribed constituents. Fourteen days are allowed from delivery of the goods or of the statutory statement, whichever is later, for taking a sample to check this statement. It is an offence to withhold the statutory statement, but the statement is, itself, nothing more than a civil warranty. If it is not fulfilled, subject to the permissible amounts of variation, the purchaser has a civil claim against his supplier; but there can be no prosecution in respect of any false statement made in it. In the case of feeding stuffs, the principal constituents which must be the subject of the warranty are oil and protein, although phosphoric acid has to be declared in certain instances, and fibre (because of its negative value) in others. The particulars to be guaranteed in respect of fertilisers are generally the amounts of nitrogen, phosphoric acid, and potash, though they vary according to the article, and include, in the case of basic slag and phosphate rock, a statement as to the fineness of grinding.

The various fertilisers and feeding stuffs coming within the scope of the Act, together with the particulars to be declared in respect of each, are set out in the first two Schedules. The Third Schedule contains a list of substances which, if they are present in a feeding stuff, must be declared. The Fourth Schedule consists of definitions of the names of the common fertilisers and feeding stuffs; and the Act provides that the sale of an article under one of the defined names constitutes a warranty that the article accords with the definition. The Fifth Schedule contains a list of articles which are deemed to be " deleterious " unless the contrary is proved. It is an offence to sell or offer for sale, as a feeding stuff, any article which contains a deleterious ingredient. All these Schedules may be varied, as occasion arises, by Regulations. It is, therefore, possible to keep pace with new developments without the need for amending Acts.

Criminal proceedings for making a false statement as to the nature or analysis of an article can, in effect, now be instituted only on the evidence of a sample taken on the premises of the person to be prosecuted. In order to connect the article sampled with a description, a requirement of marking parcels has been imposed, though this requirement applies only to articles shown in the First Schedule, not to all those which are subject to the civil provisions.

The mark to be applied to First Schedule articles may be either the actual particulars which are required to be given in the statutory statement, or a symbol (such as a combination of letters or numerals), the meaning of which is entered in a register kept for the purpose. Inspectors appointed under the Act have power to enter any premises where there are scheduled fertilisers and feeding stuffs which have been prepared for sale or consignment, and to take samples for the purpose of comparing the particulars marked on the parcel with the results of analysis of the sample.

FERTILISERS AND FEEDING STUFFS ACT, 1926, THE (*Continued*)—

A number of administrative provisions are made in the Act, while the Regulations prescribe permissible limits of variation from guaranteed percentages, and lay down precise methods for marking parcels and for taking and analysing samples, besides dealing with several matters of detail; but broadly speaking the objects of the Act may be summarised in two sentences. It makes a warranty on the sale of the fertilisers and feeding stuffs in common use a statutory obligation, and provides for testing this warranty by the analysis of samples taken after delivery; and it seeks to eliminate fraud by imposing a power of inspection upon certain of these articles before they are despatched from factories and stores.

The methods of control adopted in the Dominions, while differing from each other in certain respects, have much in common. In most cases they rest upon two requirements—namely, the registration of the various " brands " of fertilisers and feeding stuffs, and the marking of each package, before sale, with particulars which have effect as a warranty. In Canada, for instance, manufacturers and importers of artificial fertilisers (with the exception of certain " straight " fertilisers which come up to specified standards) have to register each brand with the Minister of Agriculture. Applications for registration must include the name and address of the manufacturer, the brand name of the fertiliser, the guaranteed analysis, and the name of each material from which it is manufactured. Each package of fertiliser sold or held for sale must be labelled with the name of the manufacturer or importer, the brand name, the guaranteed analysis, and, if certain prescribed organic materials are present, their percentage by weight. A similar set of provisions exists in regard to " commercial feeding stuffs."

The particulars of analysis for fertilisers must show the percentages of water-soluble nitrogen, total nitrogen, available phosphoric acid, total phosphoric acid, and water-soluble potash; and in the case of basic slag and rock phosphate, or mixtures of these two, the fineness of grinding. The percentages of oil, protein, and fibre must be declared in respect of feeding stuffs.

In Australia, New Zealand, and South Africa the same general principles are to be found in the laws regulating the sale of fertilisers and feeding stuffs as those which underlie the Canadian enactments.

A. T. A. D.

FERTILIZERS, ARTIFICIAL, VALUATION OF—There is available for the farmer a wide choice of artificial manures, which vary not only in composition but also in price per ton.

Many of these manures serve the same purpose, and the final selection should therefore be made on price. For example, if a quick-acting nitrogenous manure is required, it is probably immaterial whether nitrate of soda, nitrate of lime, nitro-chalk, or sulphate of ammonia is used; the effect of each is practically the same. It is obvious, therefore, that the manure to choose from these four would be the one which supplied nitrogen at the cheapest rate.

FERTILIZERS, ARTIFICIAL, VALUATION OF (*Continued*)—

It is quite easy to compare the manurial values of manures which contain the same constituent, though in varying amounts, and this is done by what is known as the "unit" method. This method reduces the price per ton of a manure to the cost of 1 per cent. of the particular manurial ingredient which it contains, and is arrived at by dividing the price per ton by the percentage of the constituent in the fertilizer.

Artificial manures supply chiefly three plant foods—nitrogen, phosphate, and potash. There are manures which supply these constituents either singly or in combination, but the unit method can be used first of all to compare the actual value of manures which contain the same ingredient.

Nitrogen—Taking prices per ton at the time of writing, a comparison of unit values of the different nitrogenous fertilizers is as follows:

Manure.	*Nitrogen.*	*Price per Ton.*	*Cost per Unit. of Nitrogen.*
	Per Cent.	£ s. d.	s. d.
Sulphate of ammonia	20·6	9 17 0	9 7
Nitrate of soda ..	15·5	9 17 0	12 9
Nitrate of lime ..	15·5	10 10 0	13 7
Nitro-chalk ..	15·5	9 19 0	12 10
Calcium cyanamide	20·6	8 19 0	8 8

In a case, therefore, where it is immaterial in which form nitrogen is to be applied, one should naturally choose the manure which supplies the nitrogen at the lowest rate per unit.

Phosphates—In the same way unit values are calculated for phosphatic manures, but here there is a slight complication in so far that there are some manures which supply phosphate in a water-soluble form, and others which supply it in an insoluble form. Comparison must, therefore, be made with those manures which supply the same kind of phosphates only.

Under the Fertilisers and Feeding Stuffs Act, 1928 (*q.v.*), the amount of fertilizer in phosphatic manures must be expressed in terms of phosphoric acid (P_2O_5), and unit values are therefore calculated on that basis.

Soluble Phosphates :

Manure.	*Phosphoric Acid (P_2O_5).*	*Cost of Manure per Ton.*	*Cost per Unit.*
	Per Cent.	£ s. d.	s. d.
Superphosphate	16	3 6 0	4 2
,, ...	13·75	3 0 0	4 4

It is obviously better business to buy the higher grade superphosphate, which is 2d. per unit cheaper than the lower grade.

Insoluble Phosphates :

Manure.	*Phosphoric Acid (P_2O_5).*	*Cost of Manure per Ton.*	*Cost per Unit.*
	Per Cent.	£ s. d.	s. d
Basic slag	15·75	2 9 0	3 1
Ground rock phosphate	26–27·5	2 10 0	1 10

FERTILIZERS, ARTIFICIAL, VALUATION OF (*Continued*)—

For conditions suitable to a slow-acting phosphatic manure, it is obviously better business to use ground rock phosphate than basic slag.

There are other fertilizers, the principal ingredient of which is phosphate, which contain nitrogen in addition. Before arriving at the unit value of the phosphate in such manures, the value of the nitrogen must first be deducted.

Two such manures are bone meal and steamed bone flour, and in these the unit value of the phosphoric acid is calculated as follows:

Steamed bone flour:
Nitrogen, 0·75 per cent.
Phosphoric acid, 27·5–29·75 per cent.
Price per ton, £6. 10s.

Assuming the nitrogen to have the same value as nitrogen in sulphate of ammonia, then the nitrogen in steamed bone flour is 9s. 7d. $\times$ 0·75 = 7s. 2d. The value of the phosphoric acid is, therefore, £6. 10s. *less* 7s. 2d., which is £6. 2s. 10d.

The unit value is then arrived at by dividing £6. 2s. 10d. by 28·5, which is 4s. 3d.

In the same way the unit value of the phosphoric acid in bone meal can be calculated.

Potash—The principal potassic fertilizers are kainit, potash salts, muriate of potash, and sulphate of potash. The analysis of these manures always expresses the potash as potassium oxide (K_2O). Unit values of potash in these fertilizers are, therefore, easily compared:

Manure.	*Potash.* (K_2O)	*Price of Manure per Ton.*			*Cost per Unit.*	
	Per Cent.	£	s.	d.	s.	d.
Kainit	14	3	2	0	4	5
Potash salts	30	4	17	0	3	3
Muriate of potash	50	9	2	0	3	8
Sulphate of potash	48	11	2	0	4	7

The best "value for money" is obtained by buying potash salts, 30 per cent., in preference to other potassic manures.

By this method of unit values, then, it is easily possible to decide on the best fertilizers to buy, but the method is not absolute, as there are manures which have a special value for particular crops—for example, some of the organic manures are more valuable for certain horticultural crops than inorganic manures, which may contain the same amount of fertilizing ingredients. Nevertheless, the unit value method provides the farmer with a sufficiently accurate measure of the relative value of the various artificial manures.

Still greater use can be made of this method in evaluating the many different kinds of mixed manures offered for sale. Any mixed manure is only worth the cost of the fertilizing ingredients which it contains *plus* a reasonable amount for the labour of mixing. It is fair to assume that the manufacturer of a mixed or "special" manure will use the cheapest available sources for nitrogen, phosphate, and potash, and the value of the manure should be calculated on that assumption. It has been seen that at current prices nitrogen in the form of sulphate

FERTILIZERS, ARTIFICIAL, VALUATION OF (*Continued*)—

of ammonia can be purchased at 9s. 7d. per unit; phosphoric acid (soluble) in superphosphate at 4s. 2d. per unit; phosphoric acid (insoluble) in ground mineral phosphate at 1s. 10d. per unit; and potash in muriate of potash at 3s. 8d. per unit.

To arrive at the value of any mixed manure, the number of units of each constituent is multiplied by the unit price, and the results added together. For example, in the case of a sugar-beet manure containing:

	Per Cent.
Nitrogen	6
Phosphoric acid (soluble)	6·5
Phosphoric acid (insoluble) ..	2·75
Potash	10

the valuation is:

	£	*s.*	*d.*
Nitrogen, 6 units at 9s. 7d.	2	17	6
Phosphoric acid (soluble), 6·5 units at 4s. 2d. ..	1	7	1
Phosphoric acid (insoluble), 2·75 units at 1s. 10d.	0	4	11
Potash, 10 units at 3s. 8d.	1	16	8
Total	£6	6	2

To this must be added about 10s. per ton for the cost of mixing, bagging, etc., which brings the total value to £6. 16s. 2d.

An intending purchaser, therefore, should not give more than that price for this manure, as, using only high grade materials, he can mix one giving the same analysis for this price.

It must be borne in mind that rail and credit charges may have to be added to that total, as the unit prices have been calculated on the cost prices of the manures at central markets.

REFERENCES.—Hall, "Fertilisers and Manures," John Murray, London; Watson and Moore, "Agriculture," Oliver and Boyd, Edinburgh and London; "Standard Cyclopedia of Modern Agriculture," Gresham Publishing Company, London.

J. C. L.

FERTILIZERS, RESIDUAL VALUE OF—The assessing of the unexhausted value of fertilizers is a different and in some respects more difficult task than the assessment of the manurial value of feeding stuffs. The residual values of similar applications of the same fertilizer will manifestly vary widely with the nature of the land, the crops that are grown, and the time of application.

The first important effort to study the problem was made by Voelcker and Hall, and their conclusions were published in 1917 along with the article on the manurial value of feeding stuffs already referred to. The experimental basis of their considerations, which was admittedly rather meagre, was largely derived from relevant experiments at Rothamsted and Woburn.

It was manifestly impossible to put forward any concise tables which take cognisance of variations in the nature of the soil and of the relevant crops, except that some distinction could be made between arable land and grass land assessments. The tables which were

TABLE OF COMPE SATION FOR FERT LIZERS APPLIED.

From such data as are available th following cale of compen tion may be taken de.

	On Arable Land.			On Grass Land.						
	After 1st Crop.	*After 2nd Crop.*	*After 3rd Crop.*	*After 1st Year.*	*After 2nd Year.*	*After 3rd Year.*	*After 4th Year.*	*After 5th Year.*	*After 6th Year.*	*After 7th Year.*
Superphosphate	$\frac{2}{3}$ of cost	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{2}{3}$ of cost	$\frac{1}{3}$	$\frac{1}{6}$	—	—	—	—
Bones (raw and	$\frac{2}{3}$,,	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{2}{3}$,,	$\frac{1}{2}$	$\frac{1}{3}$	$\frac{1}{6}$	—	—	—
Dissolved bones	$\frac{1}{2}$,,	$\frac{1}{4}$	$\frac{1}{12}$	$\frac{1}{2}$,,	$\frac{1}{4}$	$\frac{1}{12}$	—	—	—	—
*Basic slag and g und nineral phosphate	$\frac{2}{3}$,,	$\frac{1}{3}$	$\frac{1}{6}$	$\frac{7}{8}$,,	$\frac{3}{4}$	$\frac{5}{8}$	$\frac{1}{2}$	$\frac{3}{8}$	$\frac{1}{4}$	$\frac{1}{8}$
Bone manures	$\frac{2}{5}$,,	$\frac{1}{5}$	—	$\frac{2}{5}$,,	$\frac{1}{5}$	—	—	—	—	—
Compound manu not ont ining bone	$\frac{1}{3}$,,	$\frac{1}{6}$	—	$\frac{1}{3}$,,	$\frac{1}{6}$	—	—	—	—	—
Peruvian guano	$\frac{1}{3}$,,	$\frac{1}{6}$	—	$\frac{1}{3}$,,	$\frac{1}{6}$	—	—	—	—	—
Fish guano	$\frac{1}{3}$,,	$\frac{1}{6}$	—	$\frac{1}{3}$,,	$\frac{1}{6}$	—	—	—	—	—
Meat meal	$\frac{1}{3}$,,	$\frac{1}{6}$	—	$\frac{1}{3}$,,	$\frac{1}{6}$	—	—	—	—	—
Shoddy and wool waste, fur vaste, hair, hoofs and horns, gre ves, etc.	$\frac{1}{2}$,,	$\frac{1}{4}$	$\frac{1}{8}$	$\frac{1}{2}$,,	$\frac{1}{4}$	$\frac{1}{8}$	—	—	—	—
Manure cakes	$\frac{1}{5}$,,	$\frac{1}{10}$	—	$\frac{1}{5}$,,	$\frac{1}{10}$	—	—	—	—	—
Dried blood, sulp ate of ammonia, nitrate of soda, nitrate of lime, cyanamide	noth	ing		noth	ing					
Kainit and potash salts	$\frac{1}{2}$,,	$\frac{1}{4}$	—	$\frac{1}{2}$,,	$\frac{1}{4}$	—	—	—	—	—
Lime: deduct 4 cwts. of pure lime (or 7 cwts. of carbonate of lime) per acre, per annum ..	—	—	—	—	—	—	—	—	—	—

The valuer must exe se his discretion as o the suitability of th manures when used upon and.

Reprodu fro th *Jou al of Ministry of Agriculture and Fisheries* Augu , 1927, by pe mission of H S ationery Office.

FERTILIZERS, RESIDUAL VALUE OF (*Continued*)—

compiled by Voelcker and Hall were, therefore, intended as an approximation to the average facts, and to be modified at discretion when applied to a particular case.

Nitrogenous Fertilizers—There are some nitrogenous fertilizers, notably sulphate of ammonia, nitrate of soda, nitrate of lime, cyanamide, and dried blood, which presented a fairly clear and uncontentious case. All evidence went to show that, for the most part, there is no significant residual value from these fertilizers after the first crop has been removed. They are all either nitrates or compounds readily nitrified (see Nitrification), and are easily leached from the soil if not taken up by the crop.

A second group of nitrogenous fertilizers, of which meat meal and the guanos are typical, nitrify more slowly and, moreover, may contain some phosphate, and it was considered on the evidence available that one-third of their manurial value might be considered to remain after the first crop had been removed, and one-sixth after the second crop.

A third group, represented by wool waste and shoddy, are still slower in undergoing those changes which bring nitrogen into a soluble form, and it was considered that some residual value would remain after the third crop had been removed.

Phosphatic Fertilizers—Except in the case of certain bone manures the evidence, particularly that arising from experiments in Little Hoos Field at Rothamsted, went to show that the effect of most common phosphatic fertilizers still existed after the third crop had been removed from arable land. On grass land the effects of raw and steamed bones appeared to remain after the fourth year, and in the case of basic slag after the seventh year from application, and compensations at varying rates were suggested accordingly.

Potassic Fertilizers—The effect of potassium salts did not appear to be exhausted until the third crop had been removed in the case of arable land, and until the third year after application to grass land, and it was recommended that in the average case 50 per cent. of the value of the salts supplied should be allowed after the first crop or year, and 25 per cent. after the second.

Lime—On arable land, and still more on grass land, the effects of lime are of longer duration than those of most fertilizers, and compensation and diminishing rates were recommended after the removal of each of the first five crops, and in the case of grass land until the eighth year.

The Joint Committee already referred to, whose report was published in 1927, found little evidence to justify any serious modification of the tables published by Voelcker and Hall in 1913. They suggested some slight modification of the compensation in respect of some phosphates after the third year, and also that lime applied to land should be regarded as being lost at the rate of 4 cwts. per acre per annum, and in the case of carbonate of lime at the rate of 7 cwts. per acre per annum. With these slight modifications they republished the Voelcker and Hall tables as here printed.

N. M. C.

FIDDLE, SEED—See Flax Fiddle; also Plate XXIV, Fig. 2.

FISH—For methods of preservation by refrigeration, see Refrigeration.

FISH MANURES—See Fertilizers.

FISH MEAL—For composition and value for feeding, see Feeding Stuffs, and Poultry, Nutrition.

FLAX—The Flax Plant and its Products—"Lint" denotes both the plant *Linum usitatissimum* L. and its fibre, and is to this extent interchangeable with the term "flax." "Flax," however, has a wider significance, embracing, as it does, all the species of the genus *Linum* (*Linaceæ*). The seed of all flaxes is commonly known as linseed (lint-seed).

Linum usitatissimum is an exceedingly graceful annual plant, 20 to 40 ins. in height. The slender, erect stem is invested with small sessile, lanceolate, alternate leaves, and branches out at the top into an inflorescence of regular, pentamerous flowers, bright blue or white in colour. The capsular fruits, known as "bolls," are globular, each containing ten seeds. The seeds are smooth, glossy, heavy, and bright greenish-brown in colour; they are lenticular in transverse section, and their maximum contour is almost pear-shaped.

The fibre of commerce is the bast tissue which extends throughout the length of the stem, within the cortex, and forms an almost complete sheath round the woody pith or core. (Plate IX, Fig. 2.) The apparent length of the fibre is illusory; the long strands extracted from the plant are really bundles of longitudinally overlapping ultimate fibres gummed together by pectose. The mechanical structure of the flax fibre of commerce is thus multicellular as compared with that of the cotton fibre, which is unicellular. The actual ultimate fibres vary from $1\frac{1}{4}$ to $1\frac{3}{4}$ ins. in length, and in diameter from $\frac{1}{800}$ to $\frac{1}{1000}$ ins. or even, in the finest crops, to $\frac{1}{1200}$ ins.; they are long, straight, hollow vessels tapering gradually to points at either end. The width of the lumen has an important bearing on the quality of the fibre; in the finest fibres the lumen is almost non-existent. The chief characteristics of flax fibres are their artificial length, the fineness, strength, inelasticity, and durability of the ultimate fibres, and their capacity to absorb and to give off moisture more readily than cotton fibres.

The goods made from flax have the characteristics of the parent fibre. Linen fabrics are easily washed, and possess an unequalled gloss; certain linen towels have exceptional drying properties; linen thread is the most suitable material for an endless variety of purposes, ranging from the manufacture of lace to that of ropes, in all of which its durability, strength, and inelasticity are qualities of the greatest importance.

Linseed yields linseed oil, which on account of its natural drying properties is extensively used in the preparation of paints and varnishes. The oil is also used in the manufacture of linoleum, printers' ink, soaps, and wood preservatives.

The seed contains 31 to 39 per cent. of oil; 19 to 25 per cent. of nitrogenous substances, chiefly proteins; about 22 per cent. of nitrogen-

FLAX (*Continued*)—

free extract, mainly mucilage and hemi-cellulose; about 12 per cent. water; 5 to 6 per cent. woody fibre; and about 4 per cent. of ash.

The seed refuse after the extraction of the oil is commonly made into oilcake, a valuable cattle food. The seed bolls are often similarly used after extraction of the seed.

History of Flax Cultivation—The cultivation and preparation of flax is amongst the most ancient of all textile industries, and dates back to the remotest antiquity. Seeds and bundles of rough or unworked flax have been found in Swiss pile dwellings of the Stone Age, these bundles, technically "heads," showing every evidence of careful cleaning and assembly. According to Keller ("Lake Dwellings of Switzerland," Ferdinand Keller, trans. J. E. Lee), flax was the material used for making lines and nets for fishing and hunting, cords for carrying earthenware vessels and other heavy objects, and strong ropes which made possible the erection of buildings, menhirs, dolmens, and such memorial stones.

In ancient Egypt linen was generally worn, and was the compulsory apparel of the priests. Mummies, embalmed about 1200 B.C., have been found wrapped in fine linen, and linseed oil was used in the process of embalming. Pliny describes flax retting and cleaning processes in Egypt. After retting and sun drying, the stems were beaten with mallets on stone slabs, then the fibre was combed with iron hooks until freed from rind and pith. The tow (stupa) was distinguished from better fibre and used for wicks.

The flax crop and its vicissitudes, and linen and its preparation, are frequently mentioned in the Bible.

The plant was cultivated by the early Greeks and Romans. The Greek, Alcman, writing in the seventh century B.C., Thucydides, the historian, and Pliny, mention the seed as being used for human food; roasted linseed is still eaten in Abyssinia and the unripe capsules in Bombay (Sturtevant, "Notes on Edible Plants," *New York Expt. Stn.*, 1919).

The beginnings of flax growing in Russia, particularly Asiatic Russia, India, and the intervening countries, are lost in the mists of antiquity.

The introduction of flax into Britain is accredited to the Romans or, even more remotely, to the Phœnicians, but the earliest definite mention of Irish linen occurs, according to Sturtevant, in A.D. 500. In A.D. 1175 flax was classed by English law amongst tithable productions, and in 1531 a statute was enacted which required that of every sixty acres of land fit for cultivation, one rood should be sown with flax or hemp. The industry continued to be thus fostered and protected by legislation during the reigns of Henry VIII., Elizabeth, and George III. Anderson ("History of Commerce") has traced the manufacture of a piece of English fine linen back to 1253.

In New England flax growing commenced with the first settlement and, as early as 1640, received legislative attention.

For ages, even down to the early fourteenth century, Egyptian flax occupied foremost place in the commercial world. Amongst

PLATE IX

FIG. I.—SPECIMEN PLANTS OF FIBRE-FLAX VARIETIES ILLUSTRATING IMPROVEMENT IN THE CROP DUE TO SELECTION AND BREEDING.

Varieties No. 1 and No. 9 are Dutch commercial blue-flowered and white-flowered respectively; their shortness and general unevenness in height are characteristic of crops raised from such seed Nos. 2 to 8 are various pure line selections.

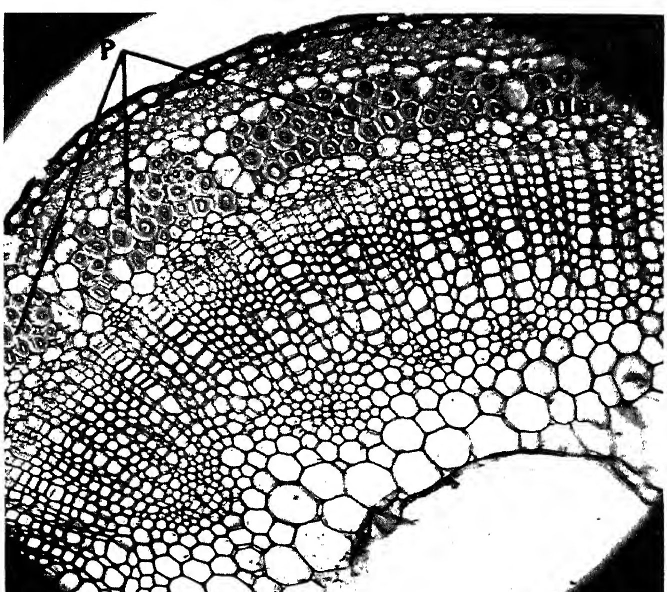


FIG. 2.—TRANSVERSE SECTION OF A FLAX STEM SHOWING THE FIBRE BUNDLES (P) MADE UP OF CLOSELY PACKED INDIVIDUAL FIBRES.

FLAX (*Continued*)—

western nations flax was, without competition, the most important of all vegetable fibres until the closing years of the eighteenth century, when, after a brief struggle, cotton took its place as the supreme vegetable fibre of commerce.

Principal World-Centres of Flax Cultivation—Flax, in one form or another, is grown in most latitudes; its cultivation for fibre is, however, normally restricted to temperate and cold zones. Bradbury, in "Flax Culture and Preparation," states that the best fibre-producing districts lie between the parallels 48° to 55° N. Vavilov traces the northern limit of flax cultivation in Europe and Asia as passing from Nikolaistad through Archangel, Pern, Tobolsk, and Yeniseisk to Vladivostok. The principal fibre-producing countries of the world are Russia, Holland, Belgium, Ireland, France, Italy, Germany, Austria, Canada, America, and Japan. Flax is also being successfully grown for fibre in Kenya Colony, practically at the Equator, at an altitude of 7,000 to 9,000 ft., and the product is of better fibre quality than Russian flax.

The chief linseed-producing countries are Argentina, India, United States of America, Canada, and Russia.

Species Used and their Origin—According to Vavilov ("Studies on the Origin of Cultivated Plants," Institute of Applied Botany and Plant Improvement, Leningrad, 1926) the flax found in the Swiss pile dwellings is probably winter flax, *L. hyemale romanum* Heer, a prostrate, trailing type still grown to a small extent in Spain, northern Italy, the Alps, Karinthia, Kraina, and mountainous Germany. Of the other flax species *L. angustifolium* Huds. is most akin to *L. usitatissimum*, and possibly should be united with it into one Linnæan species. These two yield fertile hybrids when crossed. *L. angustifolium* is still cultivated in the Canary Islands, Mediterranean coast, Asia Minor, and west Persia. *L. crepitans* Böningh, in spite of its dehiscent capsules, is still grown in Ukraine, Alpes, Schwarzwald, Würtemburg, and Switzerland.

Although some seed flaxes (as distinguished from true fibre forms) are characterized by large seed, size of seed is not an invariable feature of this type. The types of linseed suited to the Gangetic alluvium, for instance, are small-seeded, while those which are adapted to the conditions of Peninsula India are large-seeded. The root-system of the large-seeded types is not suited to the conditions of growth in the alluvium (Scientific Reports, Agric. Res. Inst., Pusa, 1927-28).

From the study of 1,400 samples of flaxes collected over Europe and Asia, Vavilov (*loc. cit.*) adduces a strong negative correlation between the duration of the vegetative period and the height of the plant. The shorter the vegetative period, the more the plant approaches the true fibre type, branching less, producing less seed, and becoming taller.

There is also a distinct connexion between the length of the vegetative period and the distribution of hereditary forms of flax to south

FLAX (*Continued*)—
and north. Indigenous southern types are late, short, branching, and prolific seed bearers, while northern forms are early, tall, unbranched, fibre types.

True seed flaxes belong only to south-west Asia. The seed flaxes of Ukraine, Caucasus and south-east European Russia are intermediate forms more nearly allied to fibre flaxes than to seed flaxes proper. The division into seed flaxes and fibre flaxes is, according to Vavilov, the result of natural selection operating in the direction south to north upon the critical character, earliness.

Pure lines show no variation in the oil content of the seed when grown either in the south or north; the oil quality changes, however, the iodine value tending to increase toward the north. Fibre flaxes, transferred to the south, branch more and grow shorter, while seed flaxes become taller when grown in North Europe. Tall mountain flax behaves in a similar way when grown at lower levels, but shows no change when transferred further south but grown at a suitable altitude. The seed-producing flaxes grown in mountainous Bokhara at altitudes of 7,000 to 9,000 feet are really fibre flaxes indistinguishable from actual European races.

Vavilov's survey of European and Asiatic races of flax reveals a marked increase in the diversity of varietal composition as India is approached. In India itself he distinguishes twenty-six botanical varieties and 123 races, all seed flaxes endemic to India.

The survey also shows that cultivated varieties from two large geographical groups corresponding at once to the oldest regions of flax cultivation and the principal centres of origin of the plant. These areas are south-west Asia (India, Bokhara, Afghanistan, Khoresm, and Turkestan), and the Mediterranean coast (Egypt, Algeria, Tunis, Spain, Italy, Greece, and Asia Minor).

In general terms, the European group is one of fibre races, and as such is quite different from the Asiatic group of seed flaxes, but there is a series of transitional types actually cultivated for both fibre and oil in Asia Minor, Caucasus, and European Russia, and these suggest the possible development of the European group out of the Asiatic. The mountainous districts of south-west Asia would certainly favour the origination and preservation of different morphological and physiological flax types. The remotest evidence available, however, goes to show that the ancient agriculturists of Mesopotamia, India, and the adjoining countries based their flax cultivation on varieties differing from the Egyptian ones. Flax cultivation in Afghanistan, Turkestan, Khoresm, and India has apparently always been for oil only, whereas both oil and fibre have always been sought in Syria, Palestine, and Egypt. Future research may yet reveal a separate centre of maximal diversity of type for these dual-purpose races.

Certain features peculiar to the flaxes of Abyssinia give colour to the tentative theory that there also a centre of origin may yet be located.

Vavilov considers that in northern Russia, Siberia, and northern European Russia natural selection, even independently of the will of man, will have gone furthest towards the discrimination of short

FLAX (*Continued*)—

vegetative period types, proportionately long-stemmed. Flax culture is very ancient in these regions, and the occurrence there of particularly valuable races might well be expected.

Extent of Flax Cultivation in Ireland—In the British Isles, flax cultivation has for many years been almost wholly an Irish industry, and there has been an increasing tendency in Ireland towards concentration of the crop in the north. Next to potatoes, flax is the most important money crop in Northern Ireland to-day. The estimated value of the crop in 1925 was £638,000.

Statistics of the acreage annually devoted to flax in Northern Ireland are available from 1847, and are presented in graph form in "The Agricultural Output of Northern Ireland, 1925" (*Min. Agric. N.I.*). In 1847 the area was 34,380 acres, and in the following year 31,389 acres. By 1853, however, the area had increased to 105,199 acres. Two years later there was a fall to 54,211 acres, but in 1861 the area had again risen to 102,056 acres. There was a large expansion in 1863 to 152,901 acres, and the maximum area of 207,107 acres was attained in 1864. The area under flax remained high during the next seven years, and did not fall below 100,000 acres until 1872. In only three subsequent years, however—in 1880, 1881, and 1918—has this level of 100,000 acres been exceeded. The smallest area ever recorded under flax in Northern Ireland was 26,334 acres in 1927, and the next lowest area was 27,450 acres in 1898. The 1928 area is given as 37,248 acres (*Fourth Ann. Rept. Agric. Statistics of N.I.*, 1928, *Min. Agric. N.I.*).

In view of the importance of the crop in the economy of Northern Ireland, the violence which characterises the fluctuations in the extent of the crop, as outlined above, is somewhat surprising. The period of maximum development in 1864 coincides with the American Civil War, and reflects the unprecedented scarcity of cotton due to that cause. The period of the World War is similarly marked by sudden increase in acreage. These causes apart, however, there always have been marked fluctuations in the area which are no doubt largely accounted for by the fact that flax is not an essential part of the rotation of crops as practised in Ireland. Temporary grass, grain, and green crops are necessarily grown in systematic rotation, as they are essential for either the cleaning and amelioration of the soil or the maintenance of stock. Flax is not required for either purpose, and is grown merely as a stolen crop between two of the staple crops of the rotation when a suitable piece of land is available, and the prospects of a good price for fibre are attractive.

The crop is thus not subject to the steadying influence exercised by the rotation on the area under ordinary tillage crops, which prevents occasional poor returns affecting the acreages in succeeding years. Accordingly, a year of profitable flax growing is generally followed by an increase in the area, while a bad year has the reverse effect.

Climate and Soil—It is significant that the cultivation of flax for fibre is most successfully carried on near the sea coast, where equable

FLAX (*Continued*)—

climatic conditions of temperature and moisture, free from heavy rains and frost, and interspersed with frequent moist winds, are usual. Cool and moderately moist seasons favour the production of fine, silky, strong fibre, while hot, dry summers usually produce short and harsh, but strong, fibre.

Given the appropriate climatic conditions, flax can be grown successfully on almost any soil. Soil moisture is a very important factor; the flax plant must neither be stinted nor waterlogged. Ideally, soil conditions should be such that the moisture percolates readily in wet weather, to be retained and freely supplied by the subsoil in dry weather.

Environmental conditions generally affect the growth habit and economic qualities of the fibre, while varieties respond differentially to the same environment. Thus, a white-blossomed strain, introduced into Northern Ireland during the War when the ordinary blue-flowered seed was unobtainable, was generally regarded as inferior to the usual blue-flowered type. In at least two districts, however, a very different opinion was formed, and the white-flowered flax is now the variety preferred in these areas.

The effect of soil moisture may be critical. Seed sown in a prolonged dry spell will germinate most unevenly, some seed coming into contact with moisture and germinating at once, while the remainder lies dormant until the next shower of rain. Thus, a crop may in such cases consist of plants 10 or 12 ins. tall, and others 1 or 2 ins. in height. The backward plants remain puny throughout, and the crop entirely lacks the very desirable feature of uniformity.

There is a very widespread belief that the flax crop removes from the soil a greater proportion of nutriment than other crops. This theory of the exhaustion and deterioration of the soil by flax is very ancient, and is referred to even by Pliny, but no scientific evidence in support of the contention is forthcoming. A detailed comparison of the extractions from the soil of nutritive properties, in pounds per acre under cultivation, by flax and wheat, is quoted by Bradbury (*loc. cit.*).

	Lbs. per Acre Extracted.					
	Nitrogen.	*Phosphoric Acid.*	*Potash.*	*Lime.*	*Silica.*	*Ash.*
Flax ..	52	18	27	16	35	87
Wheat ..	35	20	35	8	116	210

In the following table the extraction values quoted above for the three essential constituents of the flax plant—nitrogen, phosphoric acid, and potash—are compared with those of some other farm crops which are based on Northern Ireland average yields:

FLAX (*Continued*)—

	Lbs. per Acre Extracted.				
	Oats.	*Potatoes.*	*Mangolds.*	*Turnips.*	*Flax.*
Nitrogen	47	47	70	76	52
Phosphoric Acid ..	31	21	32	32	18
Potash	68	81	178	113	27

From this table it appears that the flax crop in its use of soil nutriment compares favourably with other farm crops.

Position in Farm Rotation and Manuring—The above table shows also that flax may safely be sown after any crop except mangolds or turnips, an observation which is strictly in accordance with the general practice. The essential purpose of a systematic rotation of crops lies in the utilization to the best advantage of the natural productiveness of the land and the avoidance of excessive soil impoverishment in any specific plant food; it is economical and simplifies manuring problems.

The flax crop may be inserted successfully in a rotation after any cereal crop, potatoes or lea. The preferable practice is to follow the corn crop (in Northern Ireland almost exclusively oats) or to use lea ground. In certain districts flax is used as a nurse crop for grasses, whether or not these are intended for seed saving. The following are typical rotations:

Oats—Flax—Green Crop—Oats with grass seed—Hay—Grass.
Flax—Green Crop—Oats with grass seed—Hay—Grass.
Oats—Potatoes—Oats—Flax with grass seed—Hay—Grass.

In Belgium, and to a less extent in Holland, rotation crops are as thoroughly manured as garden crops are in Britain. Heavy dressings of farmyard manure are applied to the crop preceding flax, and liquid manures are applied to the land a few weeks before the flax is sown. Little use is made of artificial manures.

A strong prejudice against the use of artificial manures existed amongst farmers and flax buyers in Northern Ireland until the samples from the Department of Agriculture and Technical Instruction manurial test plots disproved the theory that such manures tended to lower fibre quality. These tests have shown clearly that the intelligent use of artificial manures improves both the yield and the quality of the fibre; the results obtained are summarized in vol. xvii., pp. 3 *et seq.* (1916), of the Department's Journal, and may be stated briefly as follows:

Sulphate of ammonia in light dressings in most cases produces a profitable increase in yield, but is unnecessary on very rich soil. Potassic manures, especially muriate of potash, are still more effective, while the most generally profitable treatment of all is a compound dressing of 1½ cwts. of muriate of potash and ½ cwt. sulphate of ammonia

FLAX (*Continued*)—

per acre. Muriate of potash is equally effective whether applied in winter or, as is the usual practice, in spring.

The use of phosphatic manures in any form is deprecated, but the value of an application of lime to the land, a year in advance of the flax crop and followed by a dressing of muriate of potash at sowing time, is exceedingly high.

Yellowing of the leaves, at one time variously ascribed to frost injury and disease, has been shown to be due entirely to lack of potash. (See Manuring, the Principles of.)

Varieties of Seed and Sources of Supply—Until the year 1914, Russia and Holland were practically the only countries of the world in which fibre flax seed saving was regularly practised. Ireland and other fibre-producing countries imported all the seed they used.

Russian seed was saved in the Baltic provinces and exported through Riga under the generic name of "Riga seed," the chief and most prized variety of which was known as "Pernau Crown." Even yet, little reliable information is available concerning the pedigree of this seed or the methods adopted in its harvesting and preparations for export. It is variously reported that portions of Russian seed are dried by the wind and sun, and that other portions are dried by artificial heat.

Exported Dutch seed formerly consisted almost entirely of Riga seed once grown in Holland on the heavier soils, and was distinguished as "Riga Child." "Riga Child" seed sown again in Holland, on lighter soils, gave rise to stocks of seed denominated "Riga Grand-child."

Large quantities of seed of both classes were imported into Ireland from Holland, and were somewhat indiscriminately known as "Dutch seed." Dutch seed was preferred to Russian as there were much greater possibilities of finding out in advance the fibre producing quality of the seed, and the Dutch methods of harvesting and preparation were known to be careful in the extreme.

During the War, Ireland's supply of flax seed became so precarious that flax growers were compelled by law to save seed from a proportion (one-eighth) of the crops. Irish seed, when well saved, proved equal in quality to any imported seed, but so great were the practical difficulties in such a wet climate, that, with the remission of the necessity, the practice did not survive. In recent years the same difficulty has been encountered in the propagation to bulk of élite strains of flax bred or selected in Northern Ireland, and it has been found necessary to conduct the later stages of propagation in England.

The sources of supply of flax seed are now more numerous than they were prior to the year 1914 or the subsequent Russian revolution, and seed is now available from Holland, Latvia, Esthonia, England, Canada, U.S.A., and Japan. In most of these countries, too, breeding work has been instituted, and pure strains of seed of named varieties are available. Each such strain is characterized by a more or less uniform performance, and its relative merits as compared with others

FLAX (*Continued*)—

having been assessed by variety trials, it can generally be relied upon to maintain the standard of excellence achieved.

The imports of flax seed into Northern Ireland during 1928 and 1927 were 42,179 cwts. and 41,954 cwts. respectively. The average retail prices per cwt. for these seasons were: Dutch 50s., Russian 48s. 6d., Riga 48s. Seed of pure strains, of English or other origin, was sold at prices in the neighbourhood of 60s. per cwt.

Samples representing most of the imported seed are submitted for analysis to the Ministry of Agriculture Seed Testing Station by merchants or farmers. The modal germination for 1928-29 is given in the Ministry's Report for that season as 92 per cent., while the modal purity of the samples was 98·5 per cent. These figures are considered to represent an import of flax seed of a good general standard. Samples in which the seed weight is less than 4 grms. per 1,000 are not usually considered good enough for sowing for fibre production.

Sowing—The standard aimed at in the preparation of the land for flax sowing is the production of a fine, firm, and porous tilth to a depth of about 6 ins. The amount of cultivation required to produce this varies with local conditions.

The seed is usually broadcast, either by hand or by a simple, but ingenious, machine known as a fiddle. (See Flax Fiddle.)

Drill sowing of flax seed as a farm practice is practically non-existent in Ireland. Most experiment stations find it a practicable, convenient, and satisfactory method which has the merit of facilitating weeding. Any vegetable seed drill can be adjusted for use with flax.

The quantity of seed sown influences both yield and quality of the resulting fibre. Thin sowing, which encourages a coarse, branching habit of growth with a resultant high seed yield and a poor, coarse, and short fibre, is used in the production of linseed (2 pecks=28 lbs. per acre), and by experiment stations interested in the rapid propagation to bulk of seed stocks of élite strains of fibre flaxes. In the latter case about 3 pecks per acre is a useful rate of seeding.

When sown for fibre, however, flax seed is applied at much heavier rates, which result in a thick "stand," tall, erect, and unbranched individuals, and a longer and finer fibre. Within limits, the thicker the seeding the finer is the fibre produced, but there has been a tendency in recent years towards a reduction in the rate of seeding in order to avoid, if possible, "lodged" crops. It is usual to increase the seeding slightly from lighter to heavier soils according to the condition of the soil.

Such considerations apart, however, the rate of seeding must depend essentially upon the purity and germination of the sample to be sown, and also, to an extent not yet generally appreciated, upon the size of the seed as indicated by the 1,000 seed weight. Seeding then varies about an average rate of 80 lbs. (about 1½ bushels) of 98 per cent. pure, 95 per cent. germinable seed weighing 4·5 grms. per 1,000 seeds. Continental seedings vary from 2 to 3 bushels per acre.

FLAX (*Continued*)—

In a letter to the *Belfast Newsletter* of 1780, a local flax grower condemns the practice of over-seeding, and mentions a successful departure from the usual rate of the time, 3 to 4 bushels, in which 6 pecks of home-saved seed per acre had given an extraordinarily fine crop.

The time of sowing depends upon (1) the climate and specific locality of the country, and (2) the nature, quality, and condition of the soil. Flax seed should be sown as early in spring as possible, since the soil is then more likely to be uniformly moist and cool than later in the season, and germination will be accordingly slower and more even. In Northern Ireland the sowing period varies from mid-April to mid-May, but there is no reason why even earlier sowing should not be practised when suitable conditions prevail. Early sowing usually entails better harvest weather, which has an important bearing on fibre quality. The danger of spring frosts, sometimes urged as an objection to early sowing, is largely over-stated. Flax plants which have germinated from accidentally scattered seeds, and which have survived the winter, surround most retting ponds.

Weeding—Unless the land is exceptionally clean, it is usual to hand weed when the braird is 2 to 4 ins. high. The practice makes for better and more easily handled crops of enhanced value. The dock (*Rumex* spp.), thistle (*Cnicus* spp.), charlock (*Sinapis arvensis*), red-shank (*Polygonum persicaria*), bindweed (*Convolvulus arvensis*), and corn marigold (*Chrysanthemum segetum*) are the most noxious weed types commonly present in Irish flax fields.

Diseases and Insect Pests—The flax crop, at least in Northern Ireland, may be said to be almost free from serious disease or pest attacks. A variety of injurious organisms is recognized, but the extent of their depredations is seldom serious.

Flax Dodder (*Cuscuta Epilinum* Weihe) is occasionally encountered.

Seedling Blight (*Colletotrichum linicolum*), which causes the death of seedlings, is transmitted on the seed, and any outbreak is contingent upon suitable climatic conditions over a short, critical period in the growth of the young plants. Browning or "Stem-break" (*Polyspora lini*) is also due to seed infection, possibly assisted in its spread by insects. The disease affects the stem of the plant, which becomes fragile, and occasions a loss of fibre.

Flax Rust or "Firing" (*Melampsora lini*) appears in the form of black areas on the stems. It is probably transmitted on fragments of the previous crop included amongst incompletely cleaned seed. Flax Wilt (*Fusarium lini*) is the real cause of the condition, apparently due to the soil, and known as "Flax Sickness" in America. Spores, which survive retting processes and which can winter in the soil, are transmitted by adhesion to the seed.

A species of Botrytis, the sclerotia of which survive the winter, kills the flax stem above the point of infection, while *Sclerotinia sclerotiorum* may occasion the rotting of lodged flax stems.

The crop, when sown on lea, is subject to the attack of Leather-Jacket grubs (*Tipula* sp.), and during the War the activities of the

FLAX (*Continued*)—

Flax Flea Beetle (*Longitarsus parvulus*) caused some alarm. Other insects which feed on flax plants include the Capsid Plant Bug (*Calocoris bipunctatus*), the Tarnished Plant Bug (*Lygus pratensis*), and the Silver Y Moth (*Plusia gamma*). (See Seed, Transmission of Diseases by.)

Harvesting—From time immemorial it has been the custom to pull flax up by the roots rather than to cut it as in the case of corn crops. In Northern Ireland, at least, the chief reason for this procedure may well lie in the fact that the flax crop is, as often as not, badly laid before harvest time, but other reasons are also advanced. It is said that flax tends to become sour and deteriorates about the point of severance when cut, and cutting would undoubtedly be wasteful of the fibre. Pulling, too, enables the crop to be freed of such weeds as infest it, and which, if cut with the crop, would impede all subsequent operations (Plate X, Fig. 1).

The increasing mechanization of farm processes has left the flax crop singularly untouched, but this is due to the failure of invention rather than to the lack of it. Many flax-pulling machines have been tried, but none has proved commercially successful in Northern Ireland. Pulling by machine is usually achieved either by the action of rotatory combs intended to engage the crop immediately below the seed bolls, or by a system of revolving endless belts between which the growing plants are nipped. Either system might work well in a standing crop, though the second method would appear to have the disadvantage of pulling weeds too, but neither can be said to be successful where a lodged crop is concerned. So interwoven does a laid flax crop become, and so completely does its lying lack uniformity of degree or direction, the hardiest inventor may well quail before the task of its disentanglement by machinery.

In countries such as Canada, where standing crops are usual, and where fibre, used as tow, is not more important than the seed crop, the combination reaper and binder is used in harvesting.

The determination of a crop's fitness for pulling requires some nicety of judgment. In Ireland, flax commences to bloom about the end of June, and the blooming period lasts for about three weeks. With its gradual cessation, growth in length also ceases, and the plant's energy becomes concentrated in the development of the seed bolls. Commencing at the base, the stem colour changes from green to yellow and the basal leaves begin to fall off. The silkiest, glossiest, and strongest fibre results from pulling at the beginning of the period of stem colour change, but most farmers prefer to err on the safer side of over-ripeness and wait until the leaves have begun to fall and the seeds to acquire a brownish tint in the capsule. Where both fibre and seed are saved, as in Belgium and Holland, the flax must, of necessity, be allowed to reach this stage of ripeness, but even in Ireland, where fibre is the only desideratum, it is estimated that for each farmer who pulls his flax too soon, five hundred pull theirs too late to secure the finest quality of fibre. A slight increase in yield is, however, gained by later harvesting. The crop is pulled by hand and tied in

FLAX (*Continued*)—

round sheaves or "beets" of uniform size, the root ends being kept together.

Uniformity in the size of beet is important in the later processes. The value of the crop is enhanced by keeping separate flax of different lengths, since otherwise the shorter straws tend to fall from the bundles into the tow during the subsequent operation of scutching, but such care in harvesting is seldom practicable.

Beets should weigh from 7 to 10 lbs. each, and five pullers of average ability will harvest a statute acre per day. The beets are assembled in twelve-beet stooks of which there should be eighty or ninety per acre.

When it is intended to save seed from fibre flaxes, harvesting is usually slightly delayed. Any small depreciation in value of the fibre thus involved is more than compensated by the value of the seed when the undertaking is attempted in suitable climatic conditions which do not entail too much extra handling of the crop in the process. The processes and methods involved are described under "Flax Seed Saving" (*q.v.*).

Retting and Scutching—The purpose of the "retting" process is to decompose by fermentation, first, the outer cortical layers of the flax stem, thus exposing the fibre; next, the adhesive pectinous substances which bind the fibre to the central woody pith; and finally the pith, to an extent which makes it easily broken. The subsequent operation of "scutching" consists in the separation of good fibre from the pith and from inferior fibre, distinguished as "tow," which accumulates as a by-product of the process.

In Northern Ireland retting is purely a farm process, and scutching is undertaken by scutch millers on a commission basis which leaves the resulting fibre and tow still the property of the farmer, who sells directly to representatives of the spinners. On the Continent these operations are more often undertaken by middlemen who specialize in them, buying the green crop from the farmer and selling the scutched fibre to the spinner. Centralized retting and scutching such as this ensures greater consistency in the quality of the product, but the system has never been established successfully in Northern Ireland. Consequently, there is much variation in the quality of Irish fibre, and the character of each farmer's product depends very largely on the facilities available for retting and on his skill in determining when the process has gone far enough. In the circumstances wide variations in practice are only natural, and the more important methods adopted are described under "Flax Retting" and "Flax Scutching" (*q.v.*).

Marketing—In Northern Ireland, flax fibre is offered for sale in markets held in the principal flax-growing districts and attended by buyers who either directly represent the spinning firms or act as middlemen.

An alternative method often followed is for buyers to visit scutch mills and inspect the produce. Bargaining between vendor and buyer is then usually conducted through the medium of the scutch

FLAX (*Continued*)—

miller, whose expert opinion of the fibre and its worth is relied upon by the farmer and guides him in making his sale.

Bradbury (*loc. cit.*) summarizes the productiveness of the fibre flax crop in the following table, in which all the yields are given in stones per statute acre of crop:

	Stones.
Freshly pulled green straw with bolls	765
Dry straw with bolls	357
Rippled dry straw	225
Retted dry straw	180
Scutched flax	32
Rescutched tow	11
Waste, showes, inferior fibre	137
Clean dry bolls	112
Clean dry seed	57
Chaff, small and broken seeds	53

While the relative proportions in this statement are no doubt reliable, the average yield of scutched flax per acre on which the other quantities depend diverges widely from the average yields published in Agricultural Output, 1925, and other official agricultural statistics.

It is a regrettable and baffling fact that, contrary to experience in other crops, the decrease in acreage of the flax crop has been accompanied by a decrease in yield. The average yield of scutched fibre per statute acre in Northern Ireland for the ten-year period 1847-56 was 39·6 stones, while for the ten-year period 1917-26 the corresponding average yield was 23·5 stones. The average annual yield in 1928 was 25·2 stones, as compared with 30·3 stones in 1927. The highest average annual yield on record is 48·0 stones in 1847, and the lowest 12·7 stones in 1871.

The average production of the flax crop in Northern Ireland has thus a dual cause of depression. The average production in tons of scutched flax for the decade 1847-56 was 15,366 tons, while the corresponding amount for the period 1917-26 was only 7,944 tons. The total production in 1928 amounted to 5,856 tons, and in 1927 to 4,988 tons only.

The following table shows the average price obtained for flax at markets in Northern Ireland, and the corresponding estimated value of the crop in each of the four seasons, 1925-1929:

Season.	*Average Price per Cwt.*		*Estimated Value of Crop.*
	s.	*d.*	£
1925–26	90	2	527,000
1926–27	73	8	444,000
1927–28	122	9	612,000
1928–29	92	11	544,000

No account is taken in the estimated crop values above of the value of re-scutched tow. The amount of tow varies greatly from season to season, and the latest year for which official returns concerning it are available is 1925. In that year the proportion of rescutched tow was estimated at 42 per cent. of the total yield of scutched flax and assessed at a value of £45 per ton, giving a total value of £110,000.

FLAX (*Continued*)—

The total value of the flax crop, including re-scutched tow, in 1925 is thus estimated at £638,000. Against this it is estimated that the total expenditure incurred by the farmers of Northern Ireland in connection with the scutching of the flax crop amounted to £113,000. Scutching is done on a commission basis at an average price (1925) of 2s. 5d. per stone.

Having regard to the requirements of the linen industry of Northern Ireland as shown by the official fibre import returns, a surprisingly large proportion of the local crop is exported. In 1928, 15,010 tons of fibre were imported and 1,472 tons exported; in 1927, the imports amounted to 23,397 tons and the quantity exported was 872 tons. Thus, in spite of large imports, almost 20 per cent. of the local crop is exported, mainly to America.

Irish flax is rather variable in quality. Much of it is equal to the finest Courtrai fibre, usually regarded as the best quality obtainable, and, in general, Irish fibre is much stronger than the Belgian or Dutch produce. Russian flax is, in general, of coarser and inferior quality than Belgian and Irish. Most of the exported Irish fibre is of a strong and rather coarse type.

Improvements in the Crop and Processes—Although the cultivation and working of flax has been practised so long in Britain, its organization into an industry is a comparatively recent development. At no very distant period practically every small Scottish and Irish farmer not only grew and retted flax, but had it scutched, spun, woven, bleached, and finished entirely within his own premises and by members of his own family. The same practice still largely prevails in other countries. This, Woodhouse ("Flax," *Encyclopædia Britannica*) points out, kept the potential industry apart from that most powerful motive toward development, the application to it of labour-saving devices; scientific inquiry, whether directed toward improvement of the crop itself, the methods of cultivation, or the subsequent processes of treatment, was similarly without incentive.

The domestic aspect of the industry drooped and ultimately died under the combined influences of the introduction of machine-spinning and power-loom weaving, and the successful challenge of cotton. The operations of spinning and weaving were merged into factory processes, and an organised industry came into being. Only then did a real need or demand for improved crops and processes supervene.

Probably the first organized effort toward improvement was that due to the famous Earl of Strafford, who, in 1636, had a number of Dutch farmers brought to Ireland to instruct the local growers in the most successful methods of treatment. From time to time since then direct financial assistance from the State has been afforded the industry. In 1711 a Linen Board was established by law to further the interests of the flax trade, and this body operated until 1828. The establishment of the Department of Agriculture and Technical Instruction for Ireland in 1899 lent a quickening, and much-needed impulse to the industry.

FLAX (*Continued*)—

This body at once instituted experimental work on all branches of the industry that directly concerned the farmer's interests, by testing experimentally varieties of seed, systems of manuring, rippling, seed-saving, retting, and scutching. It also encouraged the formation of co-operative flax societies, and instituted a prize system to create competitive cultivation, retting, scutching, etc., and so to improve the general standard of the product. The Department also bore the cost of sending annual deputations of flax growers and instructors to observe on the spot the methods of cultivating and handling the crop in Holland and Belgium.

Despite these efforts, the continued decline of the Irish flax-growing industry was the subject of a Departmental Committee's Report to Parliament in 1911, in which lack of co-operation between the interests concerned is perhaps the only substantially responsible cause brought to light. In this connexion, the centralization of retting, scutching, and marketing processes, successfully practised on the Continent to the profit of farmer, middleman, and buyer alike, though initiated several times in Ireland, has not so far been successfully established. By this method the farmer sells his crop on foot, the middleman is responsible for retting and scutching, and is in a position to sell to the flax buyers a graded and therefore more valuable product.

The rediscovery of Mendel's law in 1900 and the realization of its implications have been slower to take effect on flax than on any other crop of equal standing, although there is no inherent difficulty, such as prevalent natural crossing, to impede the application of the laws of heredity to the crop.

Mass selection of long-stemmed flax plants was first practised in Ireland by Mr. J. W. Stewart of Coleraine in 1904, but the earliest effort in this direction, according to Dorst (*Voordr. uitg. o. d. Plantenteeltdag* 30 *Juni en* 1 *Juli, Wagerungen*, 1926), was made by a Frisian farmer who, in 1816, originated the Friesche Witbloei (Frisian white-flowered) variety by the mass selection of white-bloomed plants occurring as rogues in Russian blue-flowered seed. Stewart's mass-selected seed proved superior to unselected seed. In the *Thirteenth Annual Report of the Department of Agriculture and Technical Instruction for Ireland*, 1912-13, mention is made of selection experiments on flax aimed at the isolation of élite pure strains raised from selected single plants. The work had then been in progress for three years, and sufficient seed was available for the first small-scale tests in 1914. The further development of this work, for which Dr. H. Hunter was responsible, was prevented by the War, but mention is made in subsequent reports of the development of a number of satisfactory pure strains of which No. 6, a selection from Riga seed, was probably the best. Hybridization between these strains was also begun by Hunter.

According to the eighteenth report, 1917-18, forty-four pure lines were being tested, six of which had been supplied by the great plant breeders, MM. Vilmorin, Andrieux et Cie. of Paris, and one of which was a selection from Livonian seed made by Dr. J. Vargas Eyre. The latter was an outstanding selection. One of the Department's pure

FLAX (*Continued*)—
lines was then being propagated in England, Scotland, Canada, Nairobi, France, and Ireland.

The political division of Ireland into Northern Ireland and Irish Free State again interrupted the work which now became of paramount importance in Northern Ireland. A State-aided Linen Industry Research Association which undertook research work in all branches of the industry was formed, and a Plant Breeding Station, which included flax in its purview, was established by the Ministry of Agriculture for Northern Ireland. Promising varieties bred locally or abroad are tested for their suitability for Northern Ireland by the Ministry of Agriculture, and a scheme which aims at the provision of a seed supply of the most suitable of these for Northern Ireland is now in operation.

The real difficulty of the work lies in this latter aspect of it, for since neither climate nor custom in Northern Ireland favours seed saving, the co-operation of other countries must be sought, and the only solution appears to lie in some Empire country taking up the production of seed of approved strains of flax as a commercial proposition.

Probably the best variety of fibre flax available in quantity is the selection made by Eyre, and later named "J.W.S.," in honour of Stewart, whose pioneer work has been mentioned. Dutch and Swedish pure lines are also available in commercial quantities. Great as is the advance represented by the pure strain J.W.S. over impure seed, it is likely that a good number of the new varieties bred in Northern Ireland and now under process of propagation represent an almost equally great advance over "J.W.S." (Plate IX, Fig. 1.)

Breeding is now being directed towards such definite ends as percentage of fibre, facility in retting, resistance to lodging, etc., and attempts are being made to facilitate the identification of outstanding strains, always a matter of considerable difficulty, by imposing upon them distinctive flower colours. In America, strains resistant to Wilt have been evolved, and from genetical laboratories all over the world a mass of useful genetical information concerning the flax plant is rapidly accumulating.

References.—O. W. H. Roulston, B.A., "Flax Growing in Ireland," *Farmers' Gazette*, Dublin, 1907; F. Bradbury, "Flax Culture and Preparation," Pitman and Sons, London; T. Woodhouse, "Flax," *Encyclopædia Britannica*.

I. W. S.

FLAX FIDDLE—A simple but ingenious machine used for broadcasting flax and other small seeds. The fiddle is carried in front of the sower slung by a strap from his shoulder. It consists of a seed reservoir from which seed is released in small quantities to fall on to a horizontal disc which has six narrow, vertical flanges arranged radially on its upper surface. This disc is rotated by means of a leather thong attached at both ends to a rod carried by the operator. The rod and thong are reminiscent of a violin bow and are used in much

FLAX FIDDLE (*Continued*)—
the same manner. Seed is scattered from the rotating disc by centrifugal force to a distance of 9 ft. on either side of the sower and, in expert hands, exceedingly uniform seeding can be achieved (see Plate XXIV, Fig. 2).

FLAX, RETTING—The "retting" or, literally, rotting of flax straw is a process of fermentation to which the straw is subjected as a preliminary to the extraction of fibre. Decomposition is allowed to continue until the fibre strands have been exposed by the disappearance of the outer cortical layers, and freed from the central pith by the dissolution of the pectinous substances which normally bind the two together. The pith itself is rendered more easily frangible in the process.

Fermentation is due to the activities of bacteria present in the plant itself. Both aerobic and anaerobic forms are concerned, the former beginning the process of decomposition and the latter continuing it. The initiation, maintenance, and speed of the action depend upon the suitability of various external conditions which affect the rate of propagation of the micro-organisms. The propagation of the bacteria is accelerated or retarded according to the temperature, chemical composition, and acidity or alkalinity of the growth medium, in this case, water.

Retting is variously carried out in ponds or tanks in which the water may or may not be slowly changed during the process, in sluggish streams or rivers, or by spreading the flax on grass to allow of its saturation by dew, rain, or other form of precipitation.

Pond retting in specially constructed ponds about 10 ft. wide and 4 ft. deep is the usual Irish method (Plate X, Fig. 2). The beets of undeseeded flax are placed roots downward in these ponds. They are packed loosely, and set in an inclined position in overlapping layers. The whole mass of flax is then weighted down by stones or sods placed on heavy planks. A pond 36 ft. long usually suffices for the crop from an acre. The water used should be soft, clean, clear, and free from mineral salts which may stain the fibre. The walls of the dam possess similar staining properties, though not to any harmful extent. Blue clay tints the fibre bluish, while a yellow clay imparts a pale-yellow colour.

With the commencement of retting the mass of flax tends to rise, and as the process nears completion it sinks. The system of weights is usually adjusted in such a way as to maintain the flax at a constant level, 2 or 3 ins., below the surface of the water. The process is complete when the stems break readily without bending, and when the fibre parts readily and completely from the pith. This, in favourable conditions and with a water temperature over 60° F., usually occupies eight to twelve days. Under-retting renders the subsequent mechanical processes in the production of flax more difficult, while over-retting, by the dissolution of the fibre strands themselves, will destroy their value completely.

The process is retarded if the water of the pond is slowly changed during retting, and this variation in practice is believed to produce

FLAX, RETTING (*Continued*)—

a better quality of fibre. Retting is much slower in new ponds than in old ones, as the organisms responsible accumulate in old ponds and survive as resting spores in the black mud which gathers on the pond bottoms. This deposit is often used as an infective material to accelerate the action of new dams. Dams are usually filled a few weeks before steeping time.

Retting in slowly moving rivers is most successfully carried out in the River Lys, Belgium. The water of the Lys is very deep and sluggish—the flow being about three-quarters of a mile per hour. The water is soft and contains a large amount of organic matter from the towns and villages on its banks, which, together with the enormous amount of retting carried on, ensures a continuous supply of putrefactive organisms sufficient to compensate for the quantity carried downstream by the river's motion.

Steeping extends from mid-April to mid-October, and is by no means confined to flax grown in the immediate neighbourhood. The flax beets are arranged, heads and roots alternately, in large wooden crates which are shrouded in coarse canvas to retard water movement through the flax. These crates are submerged 3 or 4 ins. below the water surface by weights, and are moored to the river bank. Retting occupies from six to nine days according to the temperature and condition of the water.

The water temperature in both pond and river retting varies from about 54° to 77° F., and, within limits, the rate of the process varies directly with increased temperature. This fact has led to the development of many systems of tank retting by which the water temperature and other contributory conditions can be controlled. Moreover, retting can be practised in this way in centrally situated localities and all the year round. The process was first promulgated by Schenk in America in 1846. The water temperatures used vary from 70° to 90° F., and retting may occupy as little as fifty hours, but the process is usually a costly one and the fibre produced is apt to give an inferior yarn.

A variation of tank-retting has been introduced by Rossi, in France, who makes use of anaerobic bacilli in pure culture, which are introduced into the warm-water vats containing the flax. The oxygen necessary to the organisms employed is provided by air continuously forced through the water. Retting by this method can be reduced to thirty-six hours.

Dew retting when practised in Ireland is usually carried out from September to mid-November, or during March and April. The flax is spread thinly and evenly in rows in a field in which the grass has been recently and closely clipped. The produce of one acre of flax will usually cover one and half acres of land when spread in this way. Retting may occupy from four to six weeks according to the moisture, temperature, and general weather conditions, and the rows are turned over at frequent intervals during the process. Dew-retted flax bleaches to a more brilliant white than water-retted flax, and for this reason must be kept separate throughout all the processes

PLATE X

FIG. I.—HARVESTING A HEAVY AND BADLY LODGED CROP OF FLAX.

FIG. 2.—TAKING FLAX FROM THE RETTING POND WHICH HAS BEEN DRAINED.

The stones at the side of the pond have been used to keep the mass of flax submerged.

By courtesy of the *Belfast Evening Telegraph.*

To face p. 410

FLAX, RETTING (*Continued*)—

of linen manufacture lest the finished fabrics appear striped. It also requires more care in spinning. In Ireland dew retting is regarded as an alternative to pond retting only to be considered in exceptional circumstances, but in many parts of Russia this method is the prevailing practice.

Retting by chemical means has not met with much success. An inherent difficulty lies in the fact that the compound which binds the ultimate fibres together in the characteristic strands is of the same composition as that which attaches these strands to the pith. Any process which disunites the ultimate fibres prior to the critical operation of wet spinning is necessarily fatal to itself.

Whatever the method of retting employed, the flax must be dried thereafter, and, while this may be done artificially by hot air, open-air drying is preferable. For drying, the flax is either spread as for dew retting or "gaited," and is afterwards reassembled in beets, stooked, and, later, stacked to await scutching.

In the Lys district it has become the custom to ret the best class of flax twice. The second retting usually occurs a year after the first, but in no case does less than one month elapse between the two rettings, and experience has shown that the longer period of storage improves the quality of the fibre. When double retting is adopted, the first steeping is naturally of shorter duration than in single retting.

I. W. S.

FLAX, SCUTCHING—The operation known as "scutching" consists in the separation of good fibre from the woody cores of the stem of the flax plant, and from inferior fibre which is incidentally segregated in the process and distinguished as "tow."

As a preliminary to scutching the beets are untied and carefully "butted" to bring all the root ends of the straws to the same level. A simple form of machine is often used for this purpose.

Scutching proper is always preceded either in the same or a separate operation by "breaking" or "crimping," a process in which the pith is broken into short lengths to facilitate its subsequent removal. Both operations are carried out in mills regularly constructed for the purpose, to which the farmer takes his retted "straw" and from which he receives his scutched flax and tow.

At no very remote period this breaking was accomplished by the use of a wooden mallet, but a more effective method was introduced when the straw was passed through a pair of wooden fluted rollers. Breaking is now usually effected by the action of a varying number of pairs of iron fluted rollers, the pitch of which may be varied to secure more complete disintegration.

The apparatus of the hand-scutcher of former days was simple in the extreme. In an upright, wooden frame or board, known as the "stock," a notch was put at about 4 ft. from the ground. The scutcher's second and remaining implement was a broad, flat, polished, hard-wood blade of birch or sycamore. A handful or "strick" of flax was placed in the notch and held there firmly by

FLAX, SCUTCHING (*Continued*)—

the left hand to be struck repeatedly downwards with the edge of the blade. New portions of the straw were continually exposed during striking until almost all the "boon" or broken pith was removed. The output of a good scutcher by this method was about 1 stone of cleaned flax per day.

The importance of good retting becomes obvious here. Scutched fibre is classified as "clean" or "dirty" according to the quantity of pith particles, in this connection termed "showes" or "shove," left adhering to the fibre. Under-retted fibre makes the complete removal of pith difficult, expensive, and wasteful of fibre, since the beating removes also all the weaker and shorter strands which accumulate as "tow," and may artificially create tow from perfectly good fibre by its violence and long continuance thus necessitated. Over-retted fibre is almost as difficult to handle, for, while the showes part readily from the fibre, comparatively light scutching may yet produce too large a proportion of tow and so cause undue loss even when the value of the tow, usually rescutched, is taken into account.

In modern mills the process is essentially the same, but the striking blade is one of a set of five or six which project radially at regular intervals from the circumference of a wheel driven by machinery. Each operative has his own stock and wheel, and it is usual to divide the labour of scutching each strick of flax between two persons—a "buffer" and a "cleaner." Both perform exactly the same operation, but the buffer's wheel is set nearer to his stock, and there are also slight differences in the manner of presenting the strick for striking, all involving a difference in the severity of the treatment as between buffing and cleaning. A mill with eight stocks and one breaker gives employment to about fifteen persons and should turn out about 60 stones of scutched flax per day.

There are two types of scutching wheels in general use, viz., Irish and Belgian. An intermediate semi-Belgian type is also occasionally seen. The Irish wheel has a heavy iron rim usually about 3 ft. in diameter to which a series of five, six, or seven blades are bolted at an angle which varies according to the scutcher's ideas. The blades, usually referred to as "handles" or "wipers," are 30 to 32 ins. in length and are generally so adjusted as to project 18 to 20 ins. beyond the periphery of the rim, giving a full diameter of about 6 ft. Each blade is about 11 ins. wide, but tapers with use towards the point. The thickness of the blade is about 1 in., but this is reduced and bevelled on the striking edge, again in accordance with individual ideas. The Belgian wheel has twelve blades each 27 ins. long and projecting 12 ins. beyond the periphery of the outer of two steel rings to which they are adjusted and attached. The blades, which are sometimes made of polished walnut, are about 5 ins. wide but taper slightly toward the point. They are less than ¼ in. in thickness and are edged on both sides for buffing, but on the further side only for cleaning. The Irish wheel is driven at from 200 to 260 revolutions per minute and the Belgian usually at from 160 to 200 revolutions per minute.

FLAX, SCUTCHING (*Continued*)—

Automatic scutching machines are at a disadvantage in that the personal factor, which bulks so largely and importantly in the process, cannot be adequately replaced. An expert scutcher using the ordinary method gives each strick of flax individual treatment to an extent which no machine can emulate. In scutching machines the straw is usually held against the blows of the blades by fluted rollers which also serve to break the boon.

I. W. S.

FLAX SEED SAVING—A fibre flax crop from which the seed is to be saved is allowed to ripen seven to ten days longer than one from which only fibre is sought. Harvesting is conducted in the usual fashion, but the subsequent process of deseeding is often simplified by assembling the crop in smaller beets, in which the handfuls of flax are laid diagonally and alternately across one another. The sheaves are arranged in pairs to form stooks, which should run north and south. The beets are turned sufficiently often to ensure complete winnowing. Sometimes the loose handfuls of pulled flax are placed in an inclined position alternately to one side or the other of a horizontal rod or wire, the whole arrangement being known as a "long gait." Alternatively the "round" or "common gait" arrangement is used in which the handfuls of flax are assembled for winnowing into hollow cones.

When partially dried the beets are usually put up in temporarily thatched windrows to dry still further before removal to a Dutch barn or more permanent stack.

Deseeding is usually delayed as long as possible, even to, as in Belgium, the beginning of the next ensuing season. The oldest and commonest method consists in drawing the flax stems freely and quickly through the teeth of a coarse, upright steel comb. The twenty-four teeth of the "rippling comb" are square in section and taper upwards to blunt points; they are set edge to edge, $\frac{3}{16}$ in. apart, each being $\frac{1}{2}$ in. in diameter, and about 13 ins. long; they occupy 20 ins. of a heavy foundation plate provided with bolt holes for its convenient and rigid fixture.

"Rippling" may be performed either indoors or out as weather conditions permit. The seed bolls, for the most part unbroken, are collected on sheets spread below the combs. This method of deseeding cannot occasion damaged seed, and has an added advantage in that weed seeds can be readily removed from the produce by the use of a $\frac{1}{4}$-in. mesh riddle. Severe rippling, however, may damage the fibre, and the method, as such, is open to the general objection of slowness both in the operation itself and in that it entails crushing of the seed bolls as a separate operation.

The comb and conveyer belt principles have been combined in at least one deseeding machine of which there are many types, all subject to allocation in one or other of two classes according to whether or not crushing is a separate operation from deseeding. The main principles employed in the first type vary from ordinary peg-drum threshing to the employment of cutting edges to sever the fine branches of the inflorescence which carry the seed bolls. Such machines are

FLAX SEED SAVING (*Continued*)—
used when tow quality fibre only is sought. Thus, in Canada flax is threshed in exactly the same way as a corn crop.

In the second type deseeding is accomplished by actual crushing of the bolls, which are either passed between smooth rollers, or subjected to stamping as in some Belgian machines. The straw is quite undamaged by such processes, but there is a possibility of injury to the seed.

Some modern machines are capable of threshing, crushing, and cleaning the seed to a preliminary extent, in one series of continuous operations, and about 8 tons of straw per hour can be threshed by one such machine in which deseeding is accomplished by peg drums, and crushing by a hummeler of a similar type to that used in clipping and awning cereals.

The further cleaning of the seed by modern methods involves the use of wind blasts, suitably meshed screens, and indented cylinders. Seeds of redshank (*Polygonum persicaria*) occasion the greatest cleaning difficulties, as they are very similar to flax seed in size, weight, and smoothness. An old Belgian method of seed cleaning, occasionally used in Ireland during the war period of compulsory seed saving, is very effective and demands no special apparatus. A large sieve, almost full of seed and suspended not quite horizontally, is swung with a peculiar circular motion, which has the effect of collecting all the light and bulky impurities together in the centre and on the surface of the seed whence they can be easily removed.

Kiln-drying of seed, sometimes used to facilitate the storage of large bulks, has much to commend it and is a perfectly safe practice. (See Seed, Artificial Drying of.)

I. W. S.

FLOWER FARMING—See Market Gardening.

FLUORINE (Symbol F; atomic weight 19·0; atomic number 9)—An extremely active, slightly yellow or buff-coloured, elementary gas. Only important in combination as fluorides. The potassium and sodium fluorides are used in casein cements, and these and others as wood preservatives and in brewing.

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF. The Aims of Research in Animal Nutrition—The science of animal nutrition is concerned mainly with securing such information as will render possible the efficient and economic feeding of farm animals. Research in this branch of biological science is directed towards the solution of the following problems: (1) what are the energy and protein requirements of the different classes of farm animals at the different stages of their life histories; (2) what are the capacities of the available feeding stuffs for supplying these requirements?

It is the purpose of this article to outline, as concisely as possible, the answers which the scientific man has given to the foregoing questions. In the first place, however, it will be desirable to say something about the functions of feeding stuffs in the nutrition of animals, and to

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
describe briefly the methods whereby it is possible to arrive at the productive value of any given feeding stuff.

What is a Feeding Stuff?—The existence of animals without plant life is not conceivable, since the plant is the elaborator of the food of animals. It alone (if we except the synthetic art of the chemist) is able to bridge the gulf between the worlds of inorganic and organic matter. Starting from simple inorganic materials like carbon dioxide and nitrates, the plant is able, under the influence of light absorbed by the chlorophyll component, to build up complex organic compounds like carbohydrates, oils, and proteins. In these substances are locked up, in the chemical or potential form, the vast stores of energy which have been derived primarily from the sun.

A feeding stuff is therefore to be regarded as a mixture of complex organic compounds in which varying amounts of solar energy have been locked up. This energy is available, in part at any rate, to the animal, which is merely, in the scientific sense, a mechanism for the transforming of energy from one form to another. The principle of the conservation of energy holds as rigidly for the animal as for the clock or the engine. Part of the energy of the food is transformed into heat for keeping up body temperature. Another part is utilized for maintaining the blood circulation and the heart beat, or for the performance of muscular work. Still another portion may become locked up in the various organic compounds which are built up in the body of the animal, such as reserve fat, the glycogen of the liver, the proteins of flesh, and the constituents of milk. Thus it is apparent that life is fundamentally a phenomenon of energy exchange, the plant in the first place utilizing and storing the energy of the sun and ultimately passing it on to the animal.

The Productive Values of Feeding Stuffs—The total locked-up energy of a feeding stuff may be determined very simply by measuring the heat evolution when a known weight of the feeding stuff is burnt in an atmosphere of compressed oxygen. This is usually referred to as the gross energy of the feeding stuff, and for its measurement a bomb calorimeter is needed. This maximum amount of energy, however, never becomes available for useful purposes in the animal organism, for the following reasons: (1) a portion of the energy leaves the body in the food residues of the fæces, such parts of the food thereby evading oxidation in the animal; (2) the full energy of the protein of the food is not liberated in the animal, since breakdown of protein does not proceed to the limiting stage of carbon dioxide, but stops short at urea, which is excreted as a waste product in the urine; (3) the intensive bacterial activity which takes place in the paunch of the ruminant uses up about 8 per cent. of the energy contained in the digestible carbohydrate and the digestible fibre of the food; (4) shortly after consumption of food, there is always a distinct rise in the rate of heat evolution from the body. This effect is known as specific dynamic action, and implies that a proportion of the energy of the food is inevitably converted into heat, a form of energy which cannot be

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

retransformed into chemical energy in the form of fat, flesh, or milk. This fraction of non-productive energy is known as the thermic energy of the food.

To arrive at the productive energy of a feeding stuff, therefore, the sum of the thermic energy and the energy losses in the liquid, solid, and gaseous excreta must be subtracted from the gross energy. The difference, known as the net energy, is a true measure of the productive value of a feeding stuff.

Starch Equivalents and Food Units—Although the Armsby system of net energy values has been widely adopted in America as the basis of measuring food values, it has not as yet attracted much attention in this country, where, for many years, the German system of starch equivalents, elaborated by Kellner, has formed the basis of successful feeding practice. The systems of Kellner and Armsby have this much in common—namely, that they seek to express the productive value of a feeding stuff in terms of its capacity to produce live-weight increase in the fattening bullock. For example, when the starch equivalent of maize is stated to be 81 per cent., it is implied that 100 lbs. of maize, when fed in addition to a maintenance diet, will produce as much fat (including protein expressed in terms of fat) in the body of an adult steer as would be produced by 81 lbs. of starch. It should be recognized, however, that the starch equivalent, although derived by a different method of experimentation, is merely the net energy value stated in another way. Since 1 lb. of starch contains 1,071 Calories of net energy, it follows that the starch equivalent of a feeding stuff multiplied by 1,071 gives the number of Calories of net energy in 100 lbs. of the feeding stuff. (See Starch Equivalent.)

A third method of assessing the productive values of feeding stuffs, —namely, the food unit system of Nils Hannson—has been employed with conspicuous success in Sweden, Norway, Denmark, and Finland, but has, for various reasons, received the scantiest recognition in English-speaking countries. The main difference between the German and Scandinavian systems lies in the fact that whereas the Kellner starch equivalents were arrived at by measuring, in experiments conducted in a respiration chamber, the actual fat-forming values of feeding stuffs when included in the rations of fattening bullocks, the Swedish feeding standards are the result of numerous feeding trials, conducted under ordinary farm conditions, with dairy cows, growing pigs, and working horses. The object of the trials was to find out in what amounts the different feeding stuffs could replace each other in the rations of animals without affecting the rate of production, in terms of meat, milk, or work, in the animal; 1 kg. of average barley, representing 1 food unit, was adopted as the standard, and the number of food units in 1 kg. of any other feeding stuff was based on the amount required to replace a given weight of the standard feeding stuff in the rations of the animals under experiment.

The Protein in the Ration—A knowledge of the starch equivalents of the various feeding stuffs enables the productive value of any ration

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
to be calculated in terms of pounds of starch or calories of net energy. The question of energy supply, however, is not the only matter to which attention must be directed. The ration must also contain enough digestible protein to meet the following requirements: (1) The repair of "worn-out" body tissue. This is referred to as the maintenance protein requirement of the animal, and represents the sole requirement of protein in the adult, non-producing animal. (2) In the young growing animal, there is a further need for protein for building up new body tissue. (3) The dairy cow also requires an extra supply of protein for synthesizing the proteins of the milk secretion. (4) In the case of the fattening animal, it is necessary to feed only a small amount of protein in excess of the maintenance requirements of the animal.

It may be laid down that the optimum results with any animal are only possible when its daily ration supplies the correct amount of energy, *i.e.*, starch equivalent, and also an amount of digestible protein adequate for the purposes of maintenance and production. The feeding of animals will be both efficient and economic when the food supply contains neither an excess nor a deficit of starch equivalent in relation to actual requirements, and when the correct balance is struck between the digestible protein and non-protein constituents of the ration.

The Maintenance Requirements of Bullocks—The term "maintenance ration" implies an amount of food which contains (1) sufficient starch equivalent for the maintenance of body temperature, heart beat, blood circulation, and other involuntary bodily processes, and for the provision of energy for voluntary muscular activity; (2) sufficient digestible protein for the repair of "worn-out" body tissue. Such a ration would enable an adult animal to maintain good health with neither gain nor loss of body weight.

In the rationing of farm animals, it is customary to provide in the first place an amount of food corresponding with the requirements for maintenance. For this purpose, such feeding stuffs as straw, hay, silage and roots are commonly employed. Having provided for these requirements, it is then necessary to add a further supply of food, in the form of concentrates, in conformation with the productive capacities of the animals. It is clear, then, that a twofold problem is involved in the investigation of the food requirements of the different types of farm animals. The requirements for maintenance and for production must be investigated separately.

The maintenance requirements of the 1,000 lb. bullock have been determined by means of balance experiments conducted in the respiration chamber (O. Kellner, "Die Ernährung der landw. Nutztiere," 1905). It has been shown that the maintenance ration should provide 6 lbs. of starch equivalent, including 0·7 lb. of digestible protein. These amounts of nutrients are contained in 14 lbs. of *good* meadow hay, and it may therefore be concluded that the maintenance ration of a 1,000 lbs. bullock is represented by 14 lbs. of good hay, plus or minus a few pounds according to the quality of the fodder and the individuality of the animal. In computing the maintenance ration, the hay may be replaced partly or wholly by mixtures such as straw and

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
roots, or straw, roots, and silage, as long as the necessary starch equivalent and digestible protein are supplied.

In calculating the maintenance rations of bullocks of differing live weights, advantage is taken of the fact that the requirements are proportional to the area of the skin surface of the animal, or, alternatively, to the two-thirds power of the weight. For example, the maintenance starch equivalent requirement of a bullock of 1,200 lbs. live weight is $6 + \frac{(1200)^{\frac{2}{3}}}{(1000)^{\frac{2}{3}}}$ lbs. It should be borne in mind, however, that this method of calculation fails to give reliable results for young animals, where the maintenance requirements are in excess of those calculated on the basis of the surface law. The magnitude of this excess is unknown in the case of cattle, so that the feeding of such young animals still belongs to the realm of the feeder's art rather than to the domain of exact science.

Requirements for Beef Production—When considering this question, it is important to realize that the chemical composition of the live-weight increase in an animal varies considerably at the different stages of its life-history. In the young animal, the gain in live weight consists mainly of water, protein, and ash, the amount of fat in such increase being small. With increasing age, however, the amount of fat in the live-weight gains increases continuously at the expense of the other constituents, until, in the last stages of fattening, the live-weight increase consists almost entirely of fat. Since 1 grm. of body fat contains 9·5 Calories of energy, whereas 1 grm. of body protein contains only 5·7 Calories, it follows that the production requirements per lb. of live-weight gain in an animal increase continuously with age and attain a maximum in the final fattening period.

A consideration of the available data from comparative slaughter and balance investigations has enabled Armsby to conclude that 1 lb. of live-weight increase in a young animal contains 2,500 Calories, in an average animal 3,250 Calories, and in an adult animal 4,000 Calories (T. B. Wood, "Animal Nutrition," 2nd edition, p. 167, Univ. Tut. Press, Cambridge, 1928). On the basis of such data, T. B. Wood ("Rations for Live Stock," p. 15, 1927) drew up the following table of requirements for live-weight increase in bullocks:

REQUIREMENTS FOR BEEF PRODUCTION.

Age and Condition of Animal.		*Requirement per Lb. of Live-Weight Gain.* *Lbs. Starch Equivalent.*
Under 2 years	Stores	2
	Fresh condition	$2\frac{1}{4}$
About 2 years	Stores	$2\frac{1}{4}$
	Fresh condition	$2\frac{1}{2}$
Over 2 years	Stores	$2\frac{1}{2}$
	Fresh condition	$2\frac{3}{4}$
	Half fat ..	3
	Fat	4

The nature of the live-weight increase in the final fattening period will be appreciated by remembering that 4 lbs. of starch equivalent

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
in the production part of the ration is able to form 1 lb. of pure fat in the body of the animal. The figures given in the table represent the food which must be given, over and above that required for maintenance, to produce 1 lb. of live-weight increase. The daily ration should not contain less than $1\frac{1}{2}$ lbs. of digestible protein.

"Baby Beef" Production—Wood and Newman have recently given some interesting figures concerning the production of "baby beef" (T. B. Wood and L. F. Newman, "Beef Production in Great Britain," 1928). Many of the calves produced in arable districts do not go through the long store period which is usual in the West Country. They are fed in such a way as to take advantage of the fact that every good-class calf is capable of increasing in weight at the rate of about 2 lbs. per day. A bullock fattened and killed at three years old has eaten, since birth, about 18,000 lbs. of food, weighed dry, of which not more than 1,000 lbs. are concentrates. His carcass yields about 800 lbs. of saleable meat. He has therefore consumed, per pound of saleable meat, $22\frac{1}{2}$ lbs. of food, weighed dry, of which only $1\frac{1}{4}$ lbs. are concentrated food. On the other hand, a "baby beef" animal, killed when eighteen months old, has eaten 7,000 lbs. of food, weighed dry, of which 1,500 lbs. are concentrates. His carcass yields 600 lbs. of saleable meat. He has therefore consumed, per pound of saleable meat, $11\frac{3}{4}$ lbs. of food weighed dry, of which $2\frac{1}{2}$ lbs. are concentrated food. These figures show that, per pound of meat produced, "baby beef" requires about twice as much concentrated food as three-year-old beef.

Requirements for Milk Production—The method of adjusting the ration of a dairy cow consists in first computing its maintenance requirements, which vary with the two-thirds power of the weight, and then adding on a further amount of food in conformation with its capacity for milk production. The maintenance requirements of a milch cow are the same as those for a bullock of equal live weight. On basis of 10 cwts. live-weight, the dairy cow requires, for maintenance, an amount of food supplying $6\frac{1}{2}$ lbs. of starch equivalent, including 0·7 lb. of digestible protein.

The amount of starch equivalent required for the production of a gallon of milk has been arrived at in the following way. If the dry matter in a gallon of average milk, containing 3·7 per cent. of fat, were burnt in a bomb calorimeter, it would give out 3,000 Calories of energy in the form of heat; the energy content of a gallon of such milk is therefore 3,000 Calories. It has been shown by Kellner that the starch value of a feeding stuff for milk production is 25 per cent. higher than its starch value for fattening. That is to say, 1 lb. of starch equivalent in the ration produces in the animal during fattening 1,071 Calories in the form of body fat, or, in the dairy cow, 1,350 Calories, *i.e.*, 25 per cent. more, in the form of milk. It follows, therefore, that the food requirement per gallon of milk is $3{,}000 \div 1{,}350 = 2\frac{1}{4}$ lbs. of starch equivalent.

Milk contains on an average about 0·4 lb. of protein per gallon. The conversion of food protein into milk protein, however, does not

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

proceed on economic lines, and it has been found by balance experiments on dairy cows that it is necessary to feed 0·55 lb. of digestible protein per gallon of milk in order to prevent the animal from losing flesh.

On the basis of these results, the standard food requirements per gallon of milk have been fixed at 2½ lbs. of starch equivalent, including 0·6 lb. of digestible protein. It should be borne in mind, however, that these data apply only to such breeds as Dairy Shorthorns, which yield milk containing about 3·7 per cent. of fat. In the case of Jersey cows, giving a high quality of milk containing as much as 4·9 per cent. of fat, the food requirement per gallon of milk rises to 3 lbs. of starch equivalent, including 0·7 lb. of digestible protein.

When supplying the maintenance requirements of dairy cows, such feeding stuffs as hay, straw, roots, and silage are usually employed, and the following rations may be cited as typical maintenance rations: (1) 14 to 20 lbs. meadow hay, the amount being dependent on the quality of the fodder; (2) 12 lbs. good meadow hay and 45 lbs. mangolds; (3) 22 lbs. silage, 4 lbs. oat straw, and 11 lbs. meadow hay. Such rations furnish approximately the starch equivalent and digestible protein requisite for maintenance.

For the purposes of milk production, it is in general necessary to employ a mixture of cereal and oil-seed products so adjusted that it contains about 75 per cent. of starch equivalent and 20 per cent. of digestible protein; such a mixture should then be used at the rate of 3⅓ lbs. for every gallon of milk. It is important that the desired amount of starch equivalent should be contained in a bulk of food which is within the limit of the cow's capacity for food consumption. Manifestly, when designing rations for farm animals in general, three primary factors must be borne in mind—energy content, balance, and bulk. The question of bulk becomes critical with animals yielding more than 4 gallons of milk daily. A 4-gallon cow will require 20 lbs of average meadow hay for maintenance and about 14 lbs. of concentrates for production. Such a ration will occasion no difficulty, since it contains about 30 lbs. of dry matter, an amount usually taken as a measure of the capacity for food consumption of such an animal. On the other hand, a 6-gallon cow may be unable, without risk of digestive disturbances, to deal with her ration of 20 lbs. of hay and 21 lbs. of cake and meal. It is necessary, therefore, to cut down the bulk.

This may be effected by substituting a mixture of bean meal and crushed oats for a portion of the hay at the rate of 2 lbs. of the mixture for 4 lbs. of hay (R. Boutflour, *Scot. J. Ag.*, viii., 133, 1925). Another method is to employ early-cut hay of high digestibility and nutritive value, so that an amount smaller than 20 lbs. will satisfy the maintenance requirements of the animal (H. E. Woodman, *Min. Agric. and Fish.*, Misc. Pub., No. 60, p. 31). The problem of bulk may also be solved simply by feeding according to the standards in the accompanying table (R. Boutflour, *Report of World's Dairy Congress*, June, 1928).

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

FEEDING STANDARDS FOR DAIRY COWS.

Milk Yield. *Gallons.*	*Hay.* *Lbs.*	*Concentrates.* *Lbs.*
4	20	14
5	16	17½
6	12	21
7	9	24½
8	6	28

As the concentrates are increased, the hay is reduced to keep the dry matter of the ration in the neighbourhood of 30 lbs. The consequent reduction of the maintenance ration is immaterial, since the thermic energy of the production ration will be usefully employed for maintaining bodily temperature. Further, since the true requirement per gallon of milk is 2¼ lbs. of starch equivalent, and the figures in the table are based on supplying 2½ lbs. for every gallon, it follows that the production ration contains a surplus of starch equivalent above actual productive requirements. This surplus, therefore, is available, if necessary, for maintenance purposes. Before dismissing this question of bulk, however, it should be pointed out that heavy-milking cows are often characterized by being able to consume much larger rations than the figures in the table suggest, especially when the ration is made up of quickly and easily digested feeding stuffs.

Requirements of Lambs, Ewes, and Fattening Sheep—Most of the recent information concerning the requirements of sheep has been derived from investigations carried out by the late Professor T. B. Wood and his associates at Cambridge. Concordant results for the maintenance requirements of adult sheep have been obtained from grass-feeding trials under carefully controlled conditions (H. E. Woodman, D. L. Blunt, and T. Stewart, *J. Agric. S.*, xvi., 205, 1926), and from the statistical treatment of the results of numerous digestion trials (T. B. Wood and J. W. Capstick, *J. Agric. Sci.*, xvi., 325, 1926). It is found to be 1·26 lbs. starch equivalent per day for a sheep of 100 lbs. live weight. The maintenance requirements of sheep of differing live weights may be calculated by the application of the surface law. On the basis of a week, the 100 lbs. sheep should receive, for maintenance, a ration containing 8·8 lbs. of starch equivalent, including not more than ½ lb. of digestible protein.

The production requirements of fattening sheep have been worked out by following three different lines of enquiry: (1) the statistical examination of the results of old feeding trials; (2) the carrying out of specially designed feeding trials; (3) the method of comparative slaughter. It is concluded (T. B. Wood, *J. Min. Agric.*, xxxiv., 295, 1927) that the best average figure for the production requirement of fattening sheep is 2½ lbs. of starch equivalent per pound of live-weight increase. In the early stages of fattening, 2 lbs. of starch equivalent will make 1 lb. of increase, while in the later stages 1 lb. of increase may require more than 3 lbs. of starch equivalent. At a live-weight of 170 lbs., 1 lb. of increase requires as much as 4 lbs. of starch equivalent. The ration should furnish about 1¾ lbs. of digestible protein per week during fattening.

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

The following conclusions have been drawn from recent investigations in respect of the requirements of ewes and lambs (T. B. Wood and W. S. Mansfield, *J. Min. Agric.*, xxxv., 211, 1928). The maintenance requirement per unit area of surface in sheep remains constant through life. It is possible, therefore, on the basis of the figure for the 100 lbs. sheep, to calculate the maintenance requirements of lambs by means of the surface law ($M=k(w)^{\frac{2}{3}}$). For a 40-lbs. lamb, for example, the maintenance requirement works out at $4\frac{1}{2}$ lbs. of starch equivalent per week. The production requirement of lambs for the first month of life is 1 lb. of starch equivalent per lb. of live weight, increasing gradually to 2 lbs. of starch equivalent as the lamb progresses to 100 lbs. live weight. The ration of the 40 lbs. lamb should also include about 1 lb. of digestible protein per week, increasing to about 2 lbs. when 100 lbs. live weight has been attained.

The production requirement of the suckling ewe is about 3 lbs. of starch equivalent per gallon of milk. Average ewe's milk contains 2·67 lbs. of starch equivalent per gallon, or 0·33 lbs. per pint. A ewe yields on an average from $2\frac{1}{2}$ to 4 pints daily. It is further concluded that the maintenance requirement of the ewe for protein is $\frac{1}{2}$ lb. digestible protein per week. To this should be added about 1 lb. of digestible protein for every gallon of milk the ewe is estimated to yield.

Requirements of Swine—The maintenance requirements of pigs have been computed from the results of basal metabolism studies conducted in animal calorimeters at Cambridge. By the term basal metabolism is implied the amount of heat given out by the animal when it is asleep and in the post-absorptive condition. If the figure be calculated on the basis of twenty-four hours, it represents the amount of energy which must be derived from the daily ration to keep the involuntary bodily functions proceeding in a normal fashion. If to the basal metabolism be added the energy expended in conscious muscular activity per day, a figure representing the maintenance requirements of the animal is obtained. It has been concluded that on an average the energy of muscular effort is equal to about 25 per cent. of the basal metabolism. The basal metabolism of a 300 lbs. large white hog has been accurately measured and shown to be 2,300 Calories per day (T. B. Wood, "Animal Nutrition," 2nd edit., p. 150, 1928). Allowing one-quarter of this for muscular effort, the maintenance requirements amount to 2,880 Calories per day. To convert this net energy into starch equivalent, it is necessary to divide by 1,500, and not by 1,071, since the pig utilizes starch equivalent more efficiently than does the ruminant animal (T. B. Wood, *J. Agric. Sci.*, xvi., 425, 1926). In the publication just cited, a graph is given showing that the basal metabolism in swine attains a maximum intensity of 72 Calories per hour per square metre of skin surface at 4 months of age. Thereafter it falls gradually and becomes constant, at a value of 43 Calories per hour per square metre, when the animal has reached the age of about 12 months. Only after this age, therefore, is Rubner's surface law obeyed by pigs. To obtain the basal metabolism, per day, of a pig at any given age, the basal metabolism per hour

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
per square metre should be read off on the graph and should be multiplied by 24 times the surface area of the animal. The surface area is given by the expression: $S=9(W)^{\frac{2}{3}}$, where W is the live-weight of the pig. To the basal metabolism should be added an allowance for normal muscular activity in order to obtain a value for the maintenance requirement. It must be confessed, however, that much work still requires to be done, both on the basal metabolism of pigs and in connection with the measurement of the energy expended by swine, under conditions of normal management, on muscular activity, before such data can form a safe basis for computing the maintenance requirements at different ages and live-weights.

The production requirements of swine have been found by the method of comparative slaughter (T. B. Wood, *J. Agric. Sci.*, xvi., 425, 1926). On the basis of 1 lb. of live weight increase, they vary from about 650 Calories of net energy in the 40 lbs. pig to 1,000 Calories in the 100 lbs. pig and 2,000 Calories in the pig of about 200 lbs. live weight, increasing to rather more than 3,000 Calories at 240 lbs. live weight. As already explained, these net energy values may be transformed into starch equivalents by dividing by 1,500.

Vitamin Requirements of Farm Animals—Prior to 1912, it was thought merely necessary, to ensure the well-being of animals, to pay attention to the energy and protein content of their rations. This view, however, has been modified by the results of recent biological research. It has been demonstrated that natural foods contain, in extremely minute amounts, some substances which are absolutely essential to the health and proper nutrition of the animal organism, especially that of the young growing animal. Five such substances, known as vitamins A, B, C, D and E, have been discovered in feeding stuffs and plant products. The absence of one or more of these substances from the diet leads in the long run to diseases of malnutrition, which can be remedied, if the disorder has not proceeded to a sufficiently acute stage, by introducing the missing vitamin into the deficient diet.

Vitamin A—The absence of this vitamin from the diet causes retardation of growth in young animals, and in the case of adult animals appears to lower the resistance of the organism to infectious disease. It is present in milk, butter, and egg yolk. Cod-liver oil is a specially rich source of vitamin A, while recent research has shown that sheep's liver oil is even richer. The farmer should bear in mind that green plants are the primary source of this accessory food factor. If it is not present in the diet of the dairy cow, then it will be absent from the milk of the animal. It has even been found possible to trace back the vitamin A, stored in the liver of the cod, to the agency of green plants. A unicellular marine plant, the diatom, *Nitzschia closterium*, synthesizes, after the manner of terrestrial green plants, vitamin A from inorganic materials. Such plants are consumed by innumerable species of small marine animals, plankton, which secure their supplies of the vitamin in this way. Again, the plankton are devoured by larger species, such as squid, small fish, etc., which in turn constitute the food of larger fish such as the cod. It follows that

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
the vitamin A stored together with the oil in the liver of the cod has for the most part passed through several organisms since it was originally manufactured in the marine plant. The green plant, therefore, is to be regarded as the sole elaborator of vitamin A.

Evidence has been accumulated in recent investigations connecting vitamin A with the hydrocarbon carotene ($C_{40}H_{56}$), one of the yellow pigments of plants and especially abundant in carrots. Although carotene is not identical with vitamin A, it appears, under certain conditions, to undergo conversion into the vitamin in the animal body. For example, if rats be fed over long periods on diets deficient in vitamin A, so that the oil in their livers fails to give the colour reaction for vitamin A (intense blue colour with antimony trichloride), then the addition of liberal amounts of carotene to the deficient diet results in a gradual storage of vitamin A in the liver.

Vitamin B—Continuous deficiency of this vitamin in the diet of animals gives rise to acute nervous disorders. The Eastern disease of beri-beri is due to the exclusive feeding on rice which has had the pericarp and most of the underlying layer of the kernel removed in the process of polishing. Fowls fed on polished rice develop a polyneuritis similar to that occurring in beri-beri. The diseased condition disappears when the rice polishings, or any products containing the vitamin B, are added to the deficient diet.

Vitamin B is contained in milk, rice bran, yeast, wheat bran and germ. Ordinary white flour is deficient in this food factor, since the object of modern milling is to remove the bran and embryo as completely as possible. Where bread forms the staple food of human beings, therefore, it would seem advisable to use wholemeal instead of white flour. With the ordinary varied human dietary, however, this is largely a matter of indifference, since the minute amounts of this vitamin which are necessary for the maintenance of health, even though absent in the bread, will readily be secured from other sources.

Vitamin C—The long absence of this vitamin from the diet leads to the condition known as scurvy. Guinea-pigs fed on a mixture of oats and bran show, at the end of about three weeks, symptoms closely resembling those of human scurvy. This condition can be cured by giving them small amounts of fresh fruit and vegetables, or extracts prepared from such materials. Vitamin C is also present in relatively large amount in succulent roots and in fresh green plant tissues. It is not present in dried seeds, but is produced during their germination, a fact which was successfully made use of during the Great War in coping with an outbreak of scurvy in the Near East.

Vitamin D—This vitamin occurs in association with vitamin A in milk and cod-liver oil. It plays an essential rôle in the normal processes of bone and teeth formation. It was noted some years ago that rickets in its early stages could often be cured by the administration of suitable doses of cream or cod-liver oil. Later it was discovered that rickets in children could also be cured by exposing their skin to sunlight, or to the rays of a lamp producing ultra-violet light ("arti-

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

ficial sunlight "). The connection between these two curative methods became clear when it was shown that rickets is caused by a deficiency of vitamin D in the body, and that this vitamin can be prepared by exposing a substance called ergosterol to the action of ultra-violet light ("irradiated ergosterol"). Ergosterol is present in the skin of animals. By exposing the skin to sunlight, the ergosterol is transformed into vitamin D for use in the organism. It is similarly manufactured in the skin of the cow, from whence it finds its way into the milk secretion.

Vitamin D can now be prepared artificially by extracting ergosterol from yeast and exposing to the action of ultra-violet light. It is stated that the addition of $\frac{1}{250000}$ grm. of such "irradiated ergosterol" to the daily diet of children will usually cure early rickets.

It has been established that the administration of preparations of vitamin D in amounts greatly in excess of an animal's requirements may lead to an acceleration of the general metabolism, particularly of the calcium metabolism. Such a condition of hypervitaminosis results in the calcification of the heart muscles, stomach wall, and lungs.

Vitamin E—This vitamin appears to be concerned in the normal processes of reproduction, and is therefore essential to fertility in the animal. Its prolonged absence from the diet has been shown to lead to sterility in rats. Red meat and wheat germ oil are rich in this food factor, although the average human diet appears to contain a sufficiency. As the discovery of this vitamin is but recent, full information concerning its nature and mode of action is not available.

Significance of Vitamins in the Nutrition of Farm Animals—The vitamin hypothesis, while affording in part an explanation of the well-recognized effects of certain feeding stuffs, has not led to any outstanding modification of the previously accepted principles of feeding practice. It has been shown that the vitamin requirements of farm animals are so small that it is matter of the greatest difficulty to devise a ration of the ordinary feeding stuffs which will produce the symptoms usually ascribed to vitamin deficiency. The farm animal most likely to suffer from vitamin deficiency is the pig, partly on account of its rapid growth, and partly on account of the fact that swine husbandry tends to proceed on more artificial lines than is the case with other classes of stock. Yet, in experiments with pigs, it has not been found possible to produce signs of malnutrition which could be ascribed to deficiency of vitamins A and C. The common home-produced feeding stuffs are satisfactory sources of vitamins, and farm animals are not likely to suffer from deficiency troubles of any kind when they are receiving properly balanced rations containing such feeding stuffs.

The distribution of the vitamins A, B, and C in the common feeding stuffs of the farm is shown in the accompanying table (H. E. Woodman, *J. Min. Agric.*, xxxv., 481, 1928). It may be for the present assumed that feeding stuffs which are rich in vitamin A will also contain some vitamin D.

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

Young pasture grass is probably the best source of vitamins on the farm. It contains in abundance the vitamins A, B, and C (and presumably D). Well-made tower silage is rich in vitamins A and B, and contains sufficient vitamin C to guard against nutritional disorders in farm animals. The vitamin content of silage, however, may be much lowered, especially in respect of vitamin C, when high temperatures are maintained over long periods of storage, or when the volume of juice draining away from the silo has been excessive. Of special interest is the fact that, of all the feeding stuffs used in winter, only roots are rich in the antiscorbutic factor C. The inclusion of roots in the rations of dairy cows must tend, therefore, to maintain the amount of the anti-scurvy factor in milk during the non-grazing winter season, a fact of considerable importance from the standpoint of infant welfare. This consideration should be borne in mind when the question of the desirability, or non-desirability, of feeding roots to dairy cows is under discussion.

VITAMINS IN FARM FEEDING STUFFS.

	Vitamin A.	*Vitamin B.*	*Vitamin C.*
Young pasture grass	Plentiful amount	Plentiful amount	Plentiful amount
Fresh lucerne ..	,, ,,	,, ,,	,, ,,
Fresh clover ..	,, ,,	,, ,,	,, ,,
Meadow hay ..	Moderate amount	Moderate amount	Trace
Tower silage ..	Plentiful amount	Plentiful amount	Small amount
Straw	None	None	None
Roots	Small amount	Small amount	Plentiful amount
Bran and middlings	,, ,,	Plentiful amount	None
Barley meal ..	,, ,,	Moderate amount	,,
Linseed cake ..	Moderate amount	Plentiful amount	,,
Cotton cake ..	,, ,,	,, ,,	,,
Coconut cake ..	Trace	Moderate amount	,,
Earth-nut cake ..	None	,, ,,	,,
Dried yeast ..	?	Plentiful amount	?
White fish meal ..	Moderate amount	?	?

On account of the richness of cod-liver oil in respect of vitamins A and D, it is but natural that arguments should have been put forward in favour of its wider use in the feeding of all classes of farm stock Golding and his co-workers (J. Golding, "Vitamins in Agriculture," *Bull.* xxxii., *Univ. College, Reading*, 1923) state that pigs kept in confinement, without access to green fodder, benefit greatly in growth and general condition if given daily doses of cod-liver oil. The requirements of large pigs are satisfied by daily additions of 1 to 2 ozs. to the diet, and it is claimed that such additions do not in any way affect the flavour of the pork or fat. The Aberdeen workers, however, deprecate the use of cod-liver oil simply and solely as a source of vitamins, on the grounds that the pig's requirements for these growth factors are inconsiderable and can readily be supplied by the use of the ordinary farm feeding stuffs. They state further that the incautious administration of fishy oils to pigs may cause a taint to appear in the cured bacon, even in cases where the fishy flavour

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
is not detectable in the fresh pork (Orr and Crichton, *Scot. J. Ag.*, vi., 279, 1923).

Promising results have been secured at Reading in connection with the use of cod-liver oil for dairy cows (Drummond, Channan, Coward, Golding, Mackintosh, and Zilva, *J. Agric. Sci.*, xiii., 144, 1923, and xiv., 531, 1924). The presence of vitamin A in cow's milk is shown to be entirely dependent on its presence in the diet of the animal. Cows stalled in the winter and fed on ordinary winter rations of seeds hay, roots, and concentrates may yield milk with only one-tenth the growth-promoting factor found in the milk of grass-fed cows. The addition of small doses of cod-liver oil to such rations induces a sharp rise in the vitamin-A value of the milk fat of the cows. No such rise is noted when oils deficient in this growth factor are given. The administration of cod-liver oil in doses from 1 to 8 ozs. per day to milking cows appears to cause no fishy taint in the milk or butter fat. A note of warning is necessary, however. The excessive administration of cod-liver oil results in a distinct lowering of the percentage of butter fat in the milk.

It is now recognized that the action of sunlight, natural or artificial, on the skin of animals results in the formation of vitamin D, a deficiency of which is associated with defective bone and teeth formation. Rickets is very liable to develop in young animals fed on diets badly balanced in regard to lime and phosphate. This liability is much reduced if the animals are allowed access to sunshine. The absorption of lime and phosphate from such rations is also greatly improved when the animals are subjected to artificial irradiation with ultra-violet light from a carbon arc lamp. These findings emphasize the importance of light and airy surroundings for growing pigs, an important matter in swine husbandry which certainly does not seem to have been recognized by bygone generations of pig feeders.

Mineral Requirements of Farm Animals—Recent research has brought to light the importance of paying attention to the amount and nature of the inorganic constituents of the rations of farm animals. It is recognized that animals are much more likely to suffer from mineral rather than from vitamin deficiency, and it is clear that the early investigators frequently attributed to lack of vitamins nutritional disorders which were, in reality, the result of deficiency or ill-balance of the mineral constituents of the diet. (See Metabolism, Mineral.)

The inorganic constituents of the animal body are as essential to life as are the energy-furnishing organic components. They stimulate and control, directly or indirectly, all the vital processes. Hydrochloric acid is essential to gastric digestion. The transport of oxygen in the blood is effected by hæmoglobin, a complex compound of iron. Alkali is necessary for the actions of the ferments ptyalin, trypsin, and amylopsin. Most important of all, lime and phosphate are required for the formation of bone and milk.

A correct diet must supply all the essential minerals. Moreover, the blood and tissues must not only receive them in proper amount, but also in correct proportions. The kidneys possess the power of

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
eliminating those minerals which are present in excess, while those which may be deficient are conserved. For example, the hydrochloric acid necessary for digestion is absorbed as salt from the digestive tract and may be used again for the production of the acid. The bones act as a storehouse of lime and phosphate, the latter being drawn on when the blood is deficient in this respect, or, alternatively, if the blood contains an excess of lime and phosphate, these are deposited in the bones.

Just as a dairy cow requires a definite amount of protein in its maintenance ration for repair of " worn-out " tissue, so it also must be supplied with definite amounts of lime and phosphate to make good the mineral losses which arise from wastage in the vital processes. A cow of average weight requires, for maintenance purposes, 1½ ozs. lime and 4/5 oz. phosphoric acid in its daily ration. In addition, it must receive a further supply of these constituents in conformation with its milk yield. One gallon of cow's milk contains ¼ oz. lime, ⅓ oz. phosphoric acid, and 1/6 oz. chlorine. As only half the mineral supply of the food is assimilated by the animal, it follows that the dairy cow should receive, per gallon of milk, and in addition to its maintenance supply, ½ oz. lime, ⅔ oz. phosphoric acid, and ⅓ oz. chlorine. It should be noted that heavy milking cows are liable to receive a deficient supply of minerals in the ordinary winter rations of the farm, and it is therefore advisable that they should be given access to a suitable mineral supplement.

One per cent. of the live weight of a store pig consists of lime and rather less than this amount of phosphoric acid. In the case of bullocks, lime represents 2 per cent. of the body weight, phosphoric acid again being present in slightly smaller amount. On the basis of a 100 lbs. live-weight increase, therefore, the pig must build into its body 1 lb. of lime and 1 lb. of phosphoric acid; the bullock must incorporate 2 lbs. of each of these constituents into every 100 lbs. of live-weight gain. As these animals are able to assimilate only half the minerals supplied in the food, twice these amounts of lime and phosphate must be supplied in the rations. A growing pig putting on 1½ lbs. of live weight per day requires ½ oz. each of lime and phosphoric acid daily. A calf growing at the same rate requires twice these amounts.

The diet of the pig is liable to be deficient in minerals, especially when the rations do not contain fish meal or dairy by-products, or when quick growth for early maturity is desired. In such cases, access to mineral mixtures should be permitted. A common supplement consists of 2 parts of steamed bone flour, 2 parts of precipitated chalk, and 1 part of common salt, the mixture being fed at the rate of 3 lbs. to every hundredweight of food. Many commercial preparations also include a small amount of potassium iodide, though when a marine product like fish meal is employed in the ration, the addition of the iodide is quite unnecessary.

The distribution of minerals in some of the common feeding stuffs of the farm is shown in the table on p. 429 (J. B. Orr, "The Importance of Mineral Matter in Nutrition," Rowett Research Institute Publi-

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

cations, vol. i., p. 189, 1925). It will be noted that the cereals in general are poor in lime and in chlorine. It requires about 40 lbs. of a mixture of oats, bran, and maize, in equal proportions, to yield ½ oz. of lime, the amount needed daily by a young growing pig. They are, on the other hand, very rich in phosphorus. Oats, among the cereals, are the best balanced in respect of mineral matter. Roots and tubers are deficient in all the minerals, especially in respect of lime. The fodders, especially leguminous plants, are rich in lime and chlorine, but relatively poor in phosphorus. Young pasture grass contains satisfactory amounts of ash; next to milk, pasture grass is the best source of balanced minerals on the farm. It should be noted that the leguminous fodders are especially rich in lime. Meals and cakes vary in composition according to their source. In general, they are rich in phosphorus and poor in lime. Fish meal is extremely rich in lime and phosphate, and to this fact is largely to be attributed the good results which follow from its inclusion in the rations of growing pigs.

MINERAL CONTENT OF FEEDING STUFFS.

	Total Ash.	*Lime.* (CaO)	*Phosphoric Acid.* (P_2O_5)	*Chlorine* (Cl)	*Iron Oxide.* (Fe_2O_3)
	Per Cent.	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Maize	1·50	0·02	0·69	0·07	0·01
Oats	3·50	0·14	0·81	0·07	0·04
Wheat	1·90	0·06	0·86	0·08	0·02
Bran	6·30	0·09	2·95	0·09	0·03
Mangolds ..	1·00	0·02	0·04	0·16	0·008
Lucerne hay ..	8·60	1·95	0·54	0·47	0·17
Red clover hay ..	7·10	1·60	0·39	0·24	0·07
Timothy hay ..	4·90	0·25	0·31	0·18	0·04
Pasture grass ..	9·78	1·00	0·74	0·95	?
Oat straw ..	5·40	0·36	0·18	0·30	?
Linseed meal ..	5·60	0·51	1·70	0·09	0·14
Fish meal ..	21·00	10·00	9·00	0·50	Trace
Whey (dry matter)	7·28	1·01	1·46	0·95	0·04

The Feeding Stuffs of the Farm—The feeding stuffs are usually divided into the following classes:

1. The *coarse fodders*, characterized by bulkiness and high content of indigestible fibre. In this group are included the cereal straws, hay of various kinds, chaff, cavings, etc.

2. The *green fodders*, such as pasture grass, kale, rape, mustard, oats and tares, green maize, sugar-beet tops, etc. They possess a high moisture content, and may be fed in the fresh condition or, in some cases, after conversion into silage.

3. *Succulent foods*, including roots, such as mangolds, turnips, swedes, etc., and tubers like potatoes. They contain high percentages of water and low percentages of crude fibre.

4. *Concentrated foods*, such as leguminous grains, oil cakes, and

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

cereal grains, and their by-products. They are characterized by containing high feeding value in small bulk.

5. *Special feeding stuffs*, such as fish meal, dried blood, meat meal, etc., mainly employed in pig feeding. In this group may also be included such by-products as dried yeast, skimmed milk, whey, molasses, etc.

It is not the purpose of this article to deal generally with the feeding stuffs. Only those cases which have been the subject of recent scientific investigation will be referred to. The reader should consult the article on Feeding Stuffs for information concerning the composition and uses of the individual feeding stuffs.

Meadow Hay—The composition of meadow hay is very variable, the percentage of protein varying between 7 and 12 per cent. in the several grades, with a corresponding variation in the amount of crude fibre of from 20 to 33 per cent. The causes of this variability in composition are threefold:

1. *Botanical Composition*—In general, the greater the content of clover, the higher the nutritive value of the hay sample. Clover enriches hay in respect of protein and lime.

2. *Weather at Time of Hay-Making*—Rain leaches out some of the soluble food nutrients from the grass and lowers its feeding value, this effect being most marked if bad weather sets in just before the hay is ready for carting.

3. *Date of Cutting*—Recent investigations at Cambridge on the nutritive value of grass point to the desirability of cutting grass for hay at an earlier stage than is at present customary (H. E. Woodman, *Min. Agric. and Fish.*, Misc. Pub., No. 60). In such a modified practice, a lighter hay crop would naturally be carted; but this circumstance would compensated for in the following ways: (*a*) the crop would be much more nutritious and richer in digestible protein; (*b*) a smaller amount of such hay would be required to satisfy the maintenance requirements of the dairy cow; (*c*) the use of such fodder would lead to the introduction of a smaller amount of useless and indigestible material into the alimentary tract of the farm animal, a point of great importance in the nutrition of the deep-milking dairy animal, which must necessarily receive very heavy rations; (*d*) such early-cut hay of high digestibility and nutritive value would constitute an ideal roughage for inclusion in the rations of early-maturing stock; (*e*) the herbage remaining after the removal of an early crop of hay would not be coarse and stubble-like in character; (*f*) the taking of an early and lighter hay crop would result in the more abundant growth of rich aftermath, of which the fullest advantage should be taken. A heavy hay crop and a big development of aftermath in one and the same year are exceptional.

It may be assumed that about 20 lbs. of the kind of hay usually made in this country is necessary to supply the maintenance requirements of the dairy cow. When, however, a good milking cow has received such an allowance of coarse fodder, it may be incapable of consuming, without risk of digestive disturbances, a sufficiency of concentrated food

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
to enable it to produce milk at its maximum capacity (see p. 419). For that reason, many a potential 1,000-gallon cow is masquerading as a low-grade animal. The efficient feeding of such an animal implies the severe cutting down of the roughage part of the ration. One excellent method of achieving this purpose is to feed early-cut hay of high nutritive value; a grade of fodder of which 10 lbs., or even less, instead of the usual 20 lbs., might be sufficient not only to meet the maintenance requirements of the animal, but also to leave over a surplus of protein for utilization in the productive processes. At what stage grass should be mown to give rise to hay of such quality cannot at present be stated with certainty, and further investigations will be necessary to elucidate this question. It is abundantly clear, however, that to allow grass to grow too mature for hay, in order to secure bulk at the expense of nutritive value, does not constitute sound practice.

Pasture Grass—Our knowledge of the composition and nutritive value of pasture grass, our most important farm feeding stuff, has undergone extensive revision as a result of a series of investigations carried out at Cambridge during the last decade (H. E. Woodman, D. L. Blunt, and J. Stewart, *J. Agric. Sci.*, xvi., 205, 1926, and xvii., 209, 1927; H. E. Woodman, D. B. Norman, and J. W. Bee, *J. Agric. Sci.*, xviii., 266, 1928, and xix., 236, 1929). These researches have brought to light the important fact that the feeding properties of pastures are primarily a function of management. By a systematic examination of the composition and digestibility of pasture herbage cut throughout the season at regular intervals, varying in the trials so far completed from one to three weeks, it has been possible to draw the following conclusions.

Pasture grass kept young and leafy by efficient and close grazing at regular intervals contains a very high percentage of protein throughout the season. Roughly one-quarter of the dry substance in such herbage consists of protein, an amount two and a half times as great as that found in grass which has been allowed to grow unchecked to the stage of maturity suitable for hay-making. Moreover, this richness in respect of protein is independent of the botanical character of the herbage, or the presence of much or little wild white clover in the pasture. On the other hand, the amount of fibre in young, leafy pasturage is very much smaller than that in meadow hay.

The digestibility of such grass compares favourably with that of linseed cake, being superior to that of a concentrate like palm-kernel cake and very much superior to the very best quality of meadow hay. Even the fibrous constituent, which in hay is often woody and of low digestibility, is, in young pasture herbage, digested to an extent equal to that of the carbohydrate fraction.

It is now recognized that the dry matter of young leafy pasturage partakes of the character of a protein concentrate of high digestibility and nutritive value. In its pre-flowering stages of growth, grass is essentially a feeding stuff designed for production rather than for maintenance purposes. This high feeding value, under a system of

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
close grazing at regular intervals, may be maintained throughout the entire season, especially when rainfall distribution serves to keep up the level of productivity during the summer period. Inadequate grazing leads to a running-off in feeding value during the second half of the season, since under such conditions the grasses are permitted to flower and seed, and to become fibrous and of diminished feeding value. For that reason, the occasional use of the mower is to be recommended, when it is found impracticable, by grazing alone, to keep the herbage young and leafy.

The protein-concentrated food produced from well managed pastures possesses advantages which are not shared by the usual farm concentrates, in that it is an excellent source of vitamins, and is further capable of supplying the requirements of farm animals for bone and milk forming minerals like lime, potash, and phosphate. With these considerations in mind, it may be claimed that the farmer's best and cheapest protein concentrate is to be found growing within easy reach of the homestead.

With the recognition of the protein-concentrated character of young pasture grass, suggestions were made for conserving the surplus produce of pastures, either in the artificially dried condition or as silage, for feeding to animals during winter as a protein concentrate. Successful experiments have already been made by the Cambridge School of Agriculture, working in collaboration with Imperial Chemical Industries, Ltd., in respect of the preservation of young pasture grass in the form of dried grass cakes (H. E. Woodman, *Farm Notes*, vol. ii., No. 4, p. 17, 1928). Immediately after cutting, the grass was dried down in steam-heated troughs, and the dried product was later compressed into the form of cakes by hydraulic presses. These dried grass cakes measured 6 by 5 ins. by 1 in., and were of such a density that 40 cubic ft. of the compressed material weighed 1 ton. They had retained the green colour of the fresh grass and had a pleasant, fragrant odour. They contained 8 per cent. of moisture and 25 per cent. of protein. On being moistened with water, they swelled up considerably and disintegrated. They were consumed eagerly by sheep, bullocks, and dairy cows, both in the dry and in the soaked condition.

Critical feeding tests were made on these dried grass cakes at Cambridge, and two main conclusions were drawn: (1) the processes of drying and pressing do not in any way impair the high nutritive properties of the fresh grass; (2) such dried grass cakes are able to replace oil cakes successfully in the winter rations of dairy cows and fattening bullocks.

On the basis of winter prices, 1 ton of dried grass cake would be worth £9 15s. for its feeding value alone. It would also have the high manurial value of about 27s. per ton. On unmanured pasture of average quality, the season's yield of dried grass cake is about 2 tons per acre. There is reason to believe, however, that first-class grassland under an intensive system of fertilizing should yield from 3 to 3½ tons of dried grass cake per acre per season.

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

Sugar-Beet and Sugar-Beet By-Products—A great deal of the farmer's interest in the newly established beet-sugar industry is centred on the values, from the feeding standpoint, of the various by-products of the beet crop—namely, sugar-beet tops, sugar-beet pulp, and beet molasses. It has been demonstrated that sugar-beet tops constitute a very useful food which is readily consumed by farm animals (H. E. Woodman and J. W. Bee, *J. Agric. Sci.*, xvii., 477, 1927). They are highly prized by the German farmer, so much so that the German sugar factories go to a great deal of trouble and expense in drying down, artificially, large masses of the wet tops for preservation for winter use. Beet tops contain as much as 85 per cent. of water, and are therefore to be classified with the succulent foods. Their most important food constituent is the sugar of the crowns, this valuable nutrient frequently amounting to as much as a fifth of the dry substance of the tops. The beet leaves are extremely rich in protein, and possess many of the nutritional virtues associated with young pasture herbage. Like other green fodders, they contain only an insignificant amount of oil. The Cambridge experiments have demonstrated the highly digestible character of beet tops, and have shown that 25 lbs. are able to replace 40 lbs. of mangolds in the rations of live stock.

Fresh beet tops contain quite appreciable amounts of oxalic acid. Wilting of the tops, however, tends to a very material reduction in the content of this harmful constituent, and for this reason it is advisable that animals should only be permitted access to tops which have been allowed to wilt for some days in the field. The further destruction of oxalic acid as a result of fermentative action in the rumen of the animal renders the risk of trouble almost negligible. Nevertheless, the results of the Cambridge experiments indicate the desirability of giving stock access to lime compounds when feeding on the tops, especially in the cases of the ewe flock and the dairy herd. Beet tops should never form more than one-third of the rations of dairy cows, though fattening bullocks may be given larger allowances. On account of their laxative effect, they should be fed with a more binding fodder like hay. Care should be exercised in the field to prevent undue contamination of the tops with soil. With the first signs of putrefaction, which may not set in until after the lapse of several weeks, feeding should be discontinued, and the remainder should be ploughed into the soil as manure. Beet tops are extremely rich in minerals, and their manurial value, particularly in respect of potash, is quite considerable.

Where very large areas of sugar-beet are grown, it may only be possible to secure consumption of a fraction of the tops before decomposition sets in. In such cases, the farmer may wish to preserve a portion of the crop in the form of silage. Ensilage of the tops is best carried out in the pit or clamp, but the result is frequently disappointing, since owing to the presence of a nitrogenous compound known as betaine in the crowns, such silage readily acquires a most offensive character. Beet-top silage of excellent quality has been made by filling the whole tops into small wooden tower silos in such a manner as

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
to ensure tight packing (H. E. Woodman and A. Amos, *J. Agric. Sci.*, xvi., 406, 1926). Very satisfactory results were also obtained by following the common Continental custom of ensiling alternate layers of whole sugar-beet tops and wet sugar-beet pulp.

An investigation into the composition and feeding value of sugar-beet pulp has been carried out at Cambridge (H. E. Woodman and W. E. Calton, *J. Agric. Sci.*, xviii., 544, 1928). By sugar-beet pulp is meant the residue of the sugar-beet after extraction of most of the sugar. In the fresh condition it contains nearly 95 per cent. of water, but this is reduced to about 85 per cent. by pressing. The bulk of the wet beet pulp is dried in special drying appliances and sold under the name of dried sugar-beet pulp. At certain factories a proportion of beet molasses is added to the wet pulp prior to drying, the product being known as molasses sugar-beet pulp.

Sugar-beet pulp is to be regarded as essentially a source of carbohydrate, the dried product, on the basis of a 10 per cent. moisture content, containing as much as 59 per cent. of this constituent. The amount of sugar remaining in the dried pulp varies from 1 to 6 per cent., the main carbohydrate present consisting of pectic material. Dried beet pulp contains no more protein than does an average sample of meadow hay; it is also seriously deficient in minerals. Owing to its fairly high fibre content, it has become customary to regard dried beet pulp as possessing the character of a roughage of moderate feeding value, rather than that of a carbohydrate concentrate. The common view is to look on this feeding stuff solely as a substitute for roots in the ration, and to advise against using it for the replacement of concentrates in the productive part of the ration.

The results of the Cambridge investigations, however, have demonstrated that this view is not correct. Sugar-beet pulp has been shown to be highly digestible in the ruminant organism. In respect of the digestibility of its carbohydrate and organic matter, as well as in respect of its total content of digestible material, it compares very satisfactorily with maize meal. The process of drying the wet beet pulp in the factory does not in any way depress its digestibility. Further, from the standpoint of digestibility, it is immaterial whether dried sugar-beet pulp is included in the rations of ruminants in the dry or the soaked condition. When, however, liberal allowances of the dried product are being fed to animals, it is desirable that the food should be well softened in water prior to feeding. This procedure will ensure a higher availability of the digestible nutrients for productive purposes in the animal, and, further, will avert risk of choking trouble which sometimes arises, especially with sheep, during consumption of the dried product. The fibrous constituent of sugar-beet pulp is very little inferior in respect of digestibility to the carbohydrate component, a result which justifies the conclusion that the fibre in this feeding stuff is present almost wholly in the form of simple cellulose, unmixed with any significant amount of the indigestible lignocellulose. Attention is directed to the fact that almost four-fifths of the total dry matter of sugar-beet pulp is digested not by the normal enzymic processes,

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
but by the agency of bacteria. The digestion coefficient of the protein constituent is relatively low, and it would appear that the inclusion of sugar-beet pulp in the ration may have the effect of depressing slightly the extent to which the animal is able to utilise the protein in its food.

The final conclusion is drawn that dried sugar-beet pulp must be regarded as a carbohydrate concentrate, 1 lb. of which is capable of replacing 0·8 lb. of maize or 0·9 lb. of barley in the productive part of the rations of ruminants. Moreover, at £5 10s. per ton, it constitutes, from the standpoint of price per pound of starch equivalent, a cheap source of digestible carbohydrate in comparison with either maize meal or barley meal.

In further work at Cambridge (H. E. Woodman, A. N. Duckham, and M. H. French, *J. Agric. Sci.*, xix., p. 656, 1929) it has been shown that dried sugar-beet pulp is digested by pigs to an extent not much inferior to that to which ruminant animals are able to digest this feeding stuff. Owing to its bulky nature, however, it is not a satisfactory food for inclusion in the rations of pigs which are being fed for quick growth. For breeding sows, on the other hand, or in cases where early maturity is not sought, it may be fed in moderation with a view to reducing feeding costs.

It has also been shown (H. E. Woodman, A. N. Duckham, and M. H. French, *J. Agric. Sci.*, xix., p. 669, 1929) that whole sugar beet, if suitably grated, forms an excellent substitute for barley meal in the rations of pigs. It may be fed up to 25 per cent. of the ration, the replacement being based on an equivalence between 1 lb. of barley meal and 3½ lbs. of sugar-beet.

The Influence of the Processes of Soaking, Cooking and Flaking on the Nutritive Value of Maize—It may seem strange that doubt should still exist in regard to the effect of preliminary cooking on the nutritive value of a feeding stuff, yet a survey of the literature relative to this question reveals considerable uncertainty as to whether the cooking of a feeding stuff prior to its being fed to animals leads to any material improvement in feeding value.

In view of the common practice among pig-feeders of cooking maize for swine, the results of an investigation into the influence of cooking on the nutritive value of this important feeding stuff are of interest (H. E. Woodman, *J. Agric. Sci.*, xv., 1, 1925). Digestion trials with Large White hogs were carried out with the object of instituting a comparison between dry-fed, soaked, cooked, and flaked maize. The digestion coefficients obtained in these experiments are summarized in the table given on p. 436.

The results bring out clearly the effect of preliminary treatment on the digestibility of maize. Thorough soaking raises the digestion coefficient of the maize dry matter from 85·9 to 86·9 per cent.; efficient cooking leads merely to a further small rise to 88·1 per cent. The conclusion is therefore warranted that the cooking of maize for swine is an uneconomical procedure, the gain in nutritive value not being

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—

such as to compensate for the trouble and expense of cooking and the attendant risk of the wet material turning sour if kept too long. In spite of the satisfactory results obtained for dry-fed maize, the feeding of the dry crushed grain is not recommended, since in practice it leads to a large expenditure of energy by the animal during mastication, a circumstance which results in a corresponding diminution of the productive energy of the feeding stuff. This difficulty is overcome when the grain is soaked thoroughly prior to feeding.

DIGESTION COEFFICIENTS OF MAIZE.

	Dry-fed Maize.	*Soaked Maize.*	*Cooked Maize.*	*Flaked Maize.*
	Per Cent.	Per Cent.	Per Cent.	Per Cent.
Dry matter	85·9	86·9	88·1	95·2
Organic matter	87·1	87·8	89·0	95·4
Crude protein	78·4	80·1	86·1	95·5
Ether extract	63·5	60·5	63·6	44·8
Nitrogen-free extractives ..	91·5	92·0	92·4	97·1
Crude fibre	23·1	35·3	22·6	30·5

The increase of protein digestibility from 78·4 to 86·1 per cent. as a result of cooking is noteworthy, since previous investigators, using the artificial digestion method of Stutzer, have concluded that cooking depresses the protein digestion coefficient of a feeding stuff. The inconsiderable improvement in the digestibility of the starchy constituent of maize brought about by cooking leads to the conclusions that the cellulose coatings of the starch cells are easily removed during digestion, and further, that although cooking may render the starch more easy of digestion, yet, when dealing with animals possessing extensive digestive tracts, this does not necessarily imply a more complete digestion of the constituent in question.

The high value obtained for the digestion coefficient of the dry matter of flaked maize is of special interest in view of the efforts of certain commercial enterprises to popularize this form of maize with the stock-feeder. In the manufacture of flaked maize, the grain is submitted to the several processes of screening, steaming, rolling, and drying. The resulting product consists of crisp, yellow flakes composed almost entirely of protein and soluble starch. It is probable that the high digestibility of these constituents is to be attributed to their presence in the feeding stuff in a form easily accessible to digestive ferments in the alimentary tract. Flaked maize is an ideal food for inclusion in the rations of heavy-milking cows and of animals which are being fed for early maturity.

The Grading, Composition, and Feeding Value of Millers' Offals—Before the war, four grades of wheaten offals were on the market—namely, bran, pollards, coarse middlings, and fine middlings. An investigation carried out at Cambridge (H. E. Woodman, *J. Agric. Sci.*,

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—
xiii., 483, 1923) revealed the fact that the period of Government control of the milling industry during the Great War left, as an apparently permanent effect, a much simpler method of grading offals. Pollards have entirely disappeared as a separate grade and only small amounts of fine middlings are now finding their way on to the market. Only two grades, namely, bran and coarse middlings, are produced in quantity.

In the year 1923 the writer was engaged in an investigation dealing with the grading, composition, and feeding value of post-war wheaten offals. It was shown that a simple, uniform method of grading offals on the basis of size of particles always yielded fractions which were characterized by a perfectly distinctive chemical composition, both in respect of crude and digestible nutrients, and also by the possession of well-defined feeding values. The composition and feeding values of these grades are shown in the accompanying table:

COMPOSITION OF WHEAT OFFALS GRADED ACCORDING TO SIZE OF PARTICLES (DRY MATTER BASIS).

	Grade 1 (*Bran*).	*Grade* 2 (*Middlings*).	*Grade* 3 (*Fine Middlings*).
	Per Cent.	Per Cent.	Per Cent.
Crude protein	17·32	18·38	19·64
Ether extract	4·44	5·67	4·83
Nitrogen-free extractives	60·71	66·05	70·16
Crude fibre	10·87	5·69	2·62
Ash	6·66	4·21	2·75
Starch equivalent	49·20	67·95	79·12

On the basis of these figures, it was but natural that the manufacturer of wheaten offals should argue that it should only be necessary, when marketing such commodities, to give a guarantee of the size of particles, without troubling to furnish any further guarantee in respect of chemical composition. Admittedly this contention would be perfectly sound in a world of honest traders, since the size of the particles in the sample of offals enables the composition and feeding value of the sample to be predicted. On the other hand, however, it would not be a difficult achievement, with the modern mill, to grind the coarser bran particles to a state of fine division and to include such material in the finer fractions like middlings and fine middlings. How serious this would be from the farmer's standpoint will readily be appreciated by comparing the starch value of bran with that of fine middlings.

To prevent such practices, advantage has been taken of the fact that the different grades of offals are characterized by markedly different fibre contents, varying from about 2·5 per cent. in the fine middlings to as much as 11 per cent. in bran or broad bran (dry matter basis). Obviously, no amount of grinding will alter the percentage of fibre in a sample of bran, so that a simple determination of the fibre

FOODS AND FEEDING, THE SCIENTIFIC ASPECTS OF (*Continued*)—content of middlings or fine middlings will reveal the adulteration of such offals with finely ground bran. For this reason, the modern Fertilisers and Feeding Stuffs Act (*q.v.*) requires that a statement of fibre content should be made when marketing the various grades of wheaten offals.

H. E. W.

FORMALDEHYDE OR FORMALIN (HCHO)—For common uses, see Insecticides and Fungicides; also Seed, Chemical Treatment of.

FRIT FLY (*Oscinella frit* Linn.): **Description and Occurrence**—Linnæus described this fly in 1750, recognizing it as the cause of light-weight grains known as frits; he estimated the annual loss in Sweden to be of the order of £100,000, a great sum in those days. Little attention was paid to it in England before Miss Ormerod reported on it during 1886; during subsequent years she acquired much useful information from farmers in relation to the life-history and ravages of the fly.

In England the adult fly is prevalent in the field throughout the year, except for the period November to April. The annual cycle consists of three generations: the first of the year swarms from the end of April to the middle of June, with a maximum prevalence about May 26; the second, from the end of May to the middle of August, with a maximum about July 15; the third, from the end of July to the beginning of November, with a maximum about August 19. Meteorological variations, even when very diverse, do not seem to affect the periods of maximum prevalence very materially; this may be due to the fact that the larva is an internal feeder and also that it is able to utilize many species of grasses as host plants. It has been bred on species of the genera *Arrhenatherum*, *Festuca*, *Lolium*, *Poa*, *Alopecurus*, *Hordeum*, etc. Of the cereals, only spring-sown oats suffer damage of economic importance in this country, wheat, barley, and rye being very slightly attacked.

Nature of Damage due to Frit Fly Attack—The fly migrates from wild grasses, where it winters in the larval stage in the stems, to spring-sown oats, no known variety being immune from attack; the eggs are laid in the soil or on the plant itself, the larva either burrowing direct to the growing point of the plant or travelling to it spirally between the leaf-sheaths. Damage at this point results in the death of the central leaf, which gives an attacked shoot a very characteristic appearance. Further, tillering is accelerated, and therefore the shoot thickens rapidly, but if the attack is severe, a stunted plant carrying many small poorly developed stems results. The presence of the larva distinguishes this type of damage from the similar type known as "tulip-root" of oats, caused by eelworm. Pupation occurs either in the surface soil or on the plant and after about fifty days from oviposition the fly of the next generation appears. The second generation of the year may oviposit on grasses, on oat tillers, or, as is more generally the case, between the paleæ on oat panicles. The larvæ totally or partially destroy the developing caryopsis, according to the time of attack, and normally, having completed their develop-

FRIT FLY (*Continued*)—

ment, they pupate within the glumes. Fritted grain varies in appearance from the so-called "blind grain," produced by early attack on the developing ovule, to the scarred caryopsis attacked only in the region of the embryo produced by late attack during the "milk" stage. A less common form of attack, on plants with panicles still ensheathed, results in the formation of "blind grain" also, due to the destruction of developing spikelets. Flies appear about thirty-five days after this second oviposition and, the cultivated plants being matured, are forced to seek wild grass plants for oviposition purposes. The reduction in the size of the fly population is very great at this time of year. The overwintering generation shows a strong preference for some grasses, *Arrhenatherum avenaceum, Hordeum murinum,* and *Agrestis myosuroides* being most readily attacked, while *Lolium perenne* appears to be much more resistant than *Lolium Italicum*; the cycle is completed in a further period of 280 days. Autumn-sown wheat is sometimes attacked if it follows late-ploughed rye-grass leys, the larvæ migrating from the buried grass stems to those of the growing crop.

The susceptibility of the primary shoot to attack is most marked during the two- and three-leaf stages of growth. Beyond the four-leaf stage susceptibility decreases very rapidly.

The influence of variety on the rate of growth of the primary shoot as expressed by rate of leaf production is practically negligible, and therefore observed differences between varieties in extent of infestation of primary shoots cannot be ascribed to variations in rates of growth of primary shoots.

Excess of nitrogen does not influence extent of shoot infestation, but may effect a reduction in extent of grain infestation.

Comparatively little is known of the parasitism of the Frit Fly. *Halticoptera fuscicornis* Walk. (Chalcidoidea) and *Rhoptromeris eucera* Htg. (Cynipoidea) are the dominant parasites, attacking the host in the larval stage and emerging from the puparia; a parasitism of the order of 37 per cent. has been observed in England. They tend to become more abundant as the season advances. Recently a nematode, parasitic in the body cavity of the fly and free-living in the débris in the stem or panicle of oats in the vicinity of the larvæ, has been described. The presence of this parasite generally results in the sterilization of the host, and parasitism of the order of 14 per cent. has been observed. At present these parasites fail to control the Frit Fly, but whether they will eventually increase sufficiently to restore the balance is not known.

Economic Losses due to Frit Fly—The annual loss caused by this minute fly in England alone is very great. During the years 1918, 1919, and 1927 the observed average losses of grain were 8 per cent., 21 per cent., and 7 per cent. respectively, and 8 to 10 per cent. is by no means a high estimate of the average annual loss of grain. Official statistics give a figure of 25 million cwts. as the average yield of oats, with a current price of about 9s. per cwt., the annual value

FRIT FLY (*Continued*)—

of grain produced being therefore about 11 million pounds sterling. Thus, an 8 per cent. loss of grain involves a monetary loss of at least 1 million pounds sterling per annum. The extent of the economic damage caused to the growing crop during the spring season is much more difficult to estimate. It is impossible for a single observer to obtain accurate data of such losses over the whole country, because the period during which observations can be made is limited to the beginning of June, and the economic value of the loss involves measurement of loss of yield. The loss of shoot may vary from practically nothing in the north to an occasional complete loss of stand in the more southern areas, and those who have had experience would agree that a conservative estimate would place the spring loss at a figure at least equivalent to that of the summer loss, giving the figure of 2 million pounds sterling as a very moderate estimate of the total economic damage which is sustained annually in England alone.

Methods of Control—The fact that the pest has been studied both here and abroad for a number of years indicates that an easy, cheap, and efficient method of chemical control is not likely to be found, and publications on the subject show that effort is now being directed towards the discovery of a type of oat plant resistant to the attack of the maggot in spring, as the chief economic damage probably occurs during this season. For four consecutive years the English varieties of oat, Goldfinder and Supreme, have shown consistent differences in extent of shoot infestation of the order of 20 per cent. in favour of Goldfinder—that is, Goldfinder is more resistant to attack than Supreme.

The question arises as to what is meant by resistance to attack. Resistance to attack may be direct or indirect, or a combination of these two methods. Direct resistance means that the shoot can resist the entry of the maggot or bring about its death before it can cause material injury. If direct resistance depends on characters such as thickness of the outer layer of the plant or toxic quality of sap, then its extent may vary with age of shoot. Indirect resistance means that while the shoots themselves may all be equally susceptible, the varieties of oat may differ in capability of producing plants or shoots per unit area, in earliness of tillering or in tillering capacity.

After attack, therefore, they may differ in their powers to recover. Indirect resistance may therefore be dependent partly on the conditions which determine growth, which, of course, will vary considerably from year to year. Resistance due to the structural nature of the plant—that is, direct resistance—is obviously the character to utilize in breeding work if possible, because its presence may be definitely established by experiment. Resistance due to such a character as tillering capability, involving recovery power—that is, indirect resistance—is difficult to measure except by the final yield of grain, and is therefore a character to explore only when the former has proved to be unworkable.

The production of new resistant varieties of economic value is being attempted by each of these methods.

FRIT FLY (*Continued*)—

The Frit Fly is very prevalent in Sweden, where many of the so-called country or local varieties of oats still exist; some have proved to be resistant to attack, the most resistant varieties known being Summer, a black oat from Gotland, in the Baltic; Spet, a local variety from Småland, a central Swedish province; and Hede, a variety commonly grown in Denmark. All these are markedly more resistant to the ravages of the fly than Victory, as is shown by the following percentage losses of primary shoots of plants grown under similar conditions: Victory, 31·5; Summer, 3·8; Spet, 5·0; Hede, 5·2 (Cunliffe, N., Various papers, *Ann. App. Biol.*, 1921-1930).

The seasonal regularity of the maximum prevalence periods of the fly in the field, the correlation between stage of growth of shoot and susceptibility to infestation, the negligible influence of variety on the rates of growth of primary shoots, and the existence of marked differences between varieties in extent of infestation when grown under similar conditions, are factors which render possible plant breeding investigations planned to solve the Frit Fly problem from the economic point of view. The results of breeding experiments now in progress seem to indicate that it will be possible to combine seed and straw qualities with capability of direct resistance to attack in the same plant. Work on indirect resistance has not proceeded very far, but there is some evidence that eventually this also may prove to be a successful line of investigation (*Ann. App. Biol.*, 1921-1930). (See Oats.)

N. C.

FRUIT—The importance of fruit in the national dietary now receives universal recognition. Several fruits—the date, bread-fruit, and the banana, for example—constitute almost a perfect food in themselves, and form a considerable proportion of the daily diet of some of the world's peoples. The chief value of fruit, however, lies in the fact that it may be consumed when ripe in the raw or uncooked state, and valuable dietetic benefits accrue from the various vegetable acids—tartaric, citric, and malic, for example—which have a marked anti-scorbutic action, and the vitamins, possessing an acknowledged nutritional value, all of which may become changed or reduced in value when the fruits are subjected to cooking processes.

A third and important value of fruit when consumed raw is the mildly laxative action promoted by the indigestible cellulose and seeds together with some of the acids. Ordinary nutritional needs are supplied by the sugars and starches, which vary considerably amongst the fresh fruits—grapes, for example, possessing a very high sugar content, and bananas a very high starch content.

The demand for fresh fruit, as in the case of vegetables, is fairly constant throughout the year. In countries such as Great Britain, with very large populations, this demand for fresh fruit can be met only by heavy importation to supplement home production. Even then the demand for fruit in some form is only partly satisfied, which explains the enormous growth in the canning industry, both at home

FRUIT (*Continued*)—

and abroad, in recent years. Some estimation of the consumption of fresh fruit in Great Britain can be gathered from the Board of Trade returns for 1930, which show that the total imports of all fresh fruits, including nuts, for that year reached the value of £34,190,603. Oranges, a fruit which has shown a progressively increased consumption during the last decade, enjoy the leading economic status with a total importation of 10,204,817 cwts. valued at £9,545,601. Apples occupy second place with a total importation of 6,182,015 cwts. valued at £7,563,849. Bananas are nearly as important, with a total of 14,991,410 bunches valued at £5,656,744. Pears and grapes are next in order of importance with values of £1,723,618 and £1,842,447, respectively. Amongst other fruits imported in a fresh state are cherries, apricots, peaches, currants, gooseberries, strawberries, plums, greengages, and damsons. Many of these fruits, such as strawberries and currants, are seasonal in character, and by reason of their perishable nature have a limited transport range from the production centre. Others—such as apples, pears, bananas, and oranges—are more durable in character, and with the aid of modern methods of transport, in which cold storage plays an important part, may be conveyed long distances by journeys occupying many weeks. (See Refrigeration.) Apples, which, we have seen, occupy the second place of importance in our fruit supplies, now reach the markets of Great Britain from Australia, New Zealand, Tasmania, Canada, Nova Scotia, and the United States, and a constant supply is thereby maintained throughout the year. Home growers have no cause to regret this state of affairs, as the constant and regular supply serves to stimulate the demand and maintain public interest in a fruit of which only a portion of the quantity consumed is produced by themselves.

Generally speaking, fruit growing is a profitable industry of the land, as in the main the world's supplies have not yet overtaken the demand. In many parts of the world the fruit-growing industry is the mainspring of the economic life of the community. It is, for example, almost the only stable source of prosperity to Jamaica (see Agriculture, West Indies), where the cultivation of the banana (*q.v.*) has more than made up for the collapse of the sugar industry, and in 1929 reached an exportable value of £2,509,878.

In Great Britain almost all the temperate fruits may be successfully grown where soil and situation are favourable, but while the supply of home-produced soft fruits and stone fruit represents about 75 per cent. of the actual consumption, the home production of dessert and cooking apples equals only approximately 50 per cent. of the actual consumption, and the bulk of this 50 per cent. consists of cooking apples. It is estimated that little more than 10 per cent. of home-produced apples are of dessert kinds.

In this connection it is interesting to note the progressive increase in the average declared value of fruit imported into Great Britain, and the annual rise in the average consumption per head of the population, which are revealed in the following table:

FRUIT (*Continued*)—

AVERAGE DECLARED VALUE OF FRUIT IMPORTED INTO GREAT BRITAIN AND IRELAND, INCLUDING RAW, DRIED, AND CANNED FRUIT.

Period.	*Average Annual Value.*	*Average Value per Head of Population.*
	£	s. d.
1882-91	7,000,000	3 11
1892-1901	9,000,000	4 7
1902-11	13,500,000	6 1
1912-21	26,500,000	11 9
1923	42,000,000	19 0
1924	45,000,000	20 1
1925	45,000,000	20 0
1926	46,500,000	20 6
1927	45,000,000	19 10

N.B.—The figures for 1923-27 are for Great Britain and Northern Ireland.

In addition to the above, it is estimated that the total annual value of home-produced fruit fluctuates between £8,000,000 and £10,000,000, representing an annual consumption of from 3s. 6d. to 4s. 5d. per head of the population.

Enough has been said to indicate the economic status of the fruit-growing industry. It remains to indicate briefly the part that is being played by scientific research in the industry's development. The statement that no other form of crop husbandry has presented so many complex problems, in the course of its development, is probably correct, and each successive year appears to add to the list. Very many of these problems are concerned with the health of the plants, bushes, or trees, as the case may be, as it is unfortunately true that most of the fruits are subject to attack by a great many predatory insects and other forms of animal life, fungus diseases, and even more obscure maladies regarded as of virus origin. These have to be dealt with either by direct combative methods or by the more subtle method of breeding immune varieties. Problems of a fundamental nature associated with propagation and nutrition have also presented themselves. Governments, recognizing the value and status of the fruit industry, have encouraged with financial assistance the maintenance of research stations, on the staffs of which are found the geneticist, the physiologist, the soil chemist, the mycologist, and the entomologist. In addition, special advisory staffs representing the last three professions are often maintained in provincial areas to render direct assistance to those engaged in the industry.

In England there are two research stations, whose activities are mainly devoted to the industry, and the work of these institutions is now linked up with colonial and dominion development by means of a bureau which was set up with the assistance of the Empire Marketing Board. Other Imperial Bureaux promote the advancement of economic entomology and mycology to the interest and welfare of the fruit grower.

Lastly, it should be emphasized that fruit growing, which has been

FRUIT (*Continued*)—

aptly described as "an art based on scientific facts," calls for the application of intelligence by all who engage in it. It is safe to say there are no rule-of-thumb practices, and each grower may have his own peculiar problems requiring study and elucidation.

The fruit trade is naturally competitive, and now calls for a high standard of marketing methods. In this respect also the home grower has received substantial encouragement from the State by the setting up of the National Mark standards of marketing, which are already applicable to apples, pears, cherries, and strawberries. (See Marketing.)

Home-produced fruits are divided into three categories for trade purposes: *Hard Fruit*, embracing apples and pears; *Soft Fruit*, which embraces strawberries, currants, raspberries, etc.; and *Stone Fruit*, a term which covers all fruits bearing a stone, such as cherries and plums.

In the following articles the cultivated fruits coming within these categories are briefly dealt with.

HARD FRUITS. (1) **The Apple** (*Pyrus Malus*)—**Introduction**—It was shown in the general article on fruit that the apple occupies the second place in economic importance amongst our fruit supplies. It is extremely popular in all countries of the world, and has established itself in favour even in the tropics, where fruit of all kinds is always readily available. The inherent edible qualities of this fruit are well known, but apart from this aspect the selling value of the dessert apple is undoubtedly attributable to the appeal made to the eye by the attractive skin colours which are a feature of most of the varieties grown commercially, both at home and abroad.

A world-wide inquiry undertaken in 1930 by Mr. W. T. Macoun, the Canadian Dominion Horticulturist, brought to light the facts that, generally speaking, the apple-consuming public is unfamiliar with names of varieties; that, in general, the colour largely determines the selling value, and that a red apple attracts the greatest number of people in all parts of the world. This information goes far to explain the popularity of such brilliantly coloured apples as Jonathan and McIntosh Red in the United States and Canada, where they are produced, and in Great Britain, where enormous quantities are imported. It also explains the popularity and selling value of Worcester Pearmain, the profitable market dessert apple of the British Isles, but which, on a quality basis, is hardly in the front rank. Edible quality in apples is, however, difficult to assess, as it varies according to national taste.

In England, and in most European countries, for example, a crisp, firm-fleshed apple is preferred, whereas in the United States and Canada soft-fleshed apples are more popular. This accounts for the position held by Worcester Pearmain in Europe, the crisp, juicy flesh outweighing the lack of flavour, and also explains why Cox's Orange Pippin, undoubtedly the leading dessert apple of the world from the point of view of flavour, is not so popular in the New World.

FRUIT (*Continued*)—

For culinary purposes large, green or greenish-yellow apples are universally preferred; the flavour must exhibit more acidity, and the flesh, when cooked, must be soft. For these reasons Bramley's Seedling, the leading culinary variety of Great Britain, is always readily disposed of and commands a high price.

As a result of the efforts of scientific research, together with the technical advice provided by the County Councils, apple growing in Great Britain is becoming established on a sounder, more extended, and more economic basis. The requirements of the markets have been studied and can now be catered for, and the mistakes made in the past need not be repeated. Owing, however, to the fact that there appears to be no late variety which, as in the case of Worcester Pearmain, can be produced on a large scale under varying conditions of soil, situation, and climate, the home grower is unable to secure anything but a very small proportion of the winter trade in dessert apples. It must be admitted that Cox's Orange Pippin, which will always command the highest prices obtainable for dessert apples in the winter, cannot be regarded as a certain and reliable cropper owing to such difficulties as pollination (this variety is self-sterile) and its dislike of certain soils and climatic conditions. On the other hand, with an accommodating and free-bearing variety such as Bramley's Seedling at his disposal the home grower should be able to cater for a very substantial proportion of the trade in culinary apples.

The Census of Production for 1925 gave the total number of apple trees, including cider apples, on commercial holdings in England and Wales as 14,828,740. The yield of fruit for that year was estimated at 6,526,000 cwts. of dessert and cooking apples, and 1,160,000 cwts. of cider apples. In the same year, 5,973,986 cwts. of dessert and cooking apples were imported. The average annual value of the apples grown in Great Britain for the years 1925-26-27 was estimated at £3,157,000. The average annual value of imported apples during these years was £8,125,000.

The chief areas of production are Kent, which is the leading county, the west midlands (Gloucester, Worcester, and Hereford), the south-western peninsula (Somerset, Devon, and Cornwall), and the eastern counties (Cambridge, Isle of Ely, Holland (Lincs.), and Norfolk). Other counties of importance are Middlesex, Essex, and Hampshire.

Apples are grown in Great Britain and Northern Ireland as plantations on cultivated land, or on the grass-orchard principle. Trees of the bush and half-standard types are usually adopted for plantations, but the standard, with stems of at least 6 ft., is the only type suitable for grass orchards in which the herbage is grazed off by sheep or eaten off by poultry. The grass-orchard is eminently suited for the production of culinary apples, and as it requires the minimum amount of attention, it is the type of production more suited to the general farmer, leaving the more intensive systems to the specialist fruit grower. In recent years commercial plantations of cordon trees, a type of tree very popular in private gardens, have been established. Cordon trees require a good deal of care and attention, but they bear

FRUIT (*Continued*)—

fruit of high quality. They are especially suitable for the high-class dessert varieties. In either case considerable care should be exercised in choosing both soil and situations for apple growing.

Soil and Climate—The soil for apples should be of good depth, and cold, very heavy clays and light, shallow sands should be avoided. The mechanical rather than the chemical condition of the soil is the more important feature, and areas with a naturally high water table are best avoided. Rainfall is another important factor which, together with climate, exercises an important bearing on the fruitfulness of apple trees. Sunny regions with rainfalls below 30 ins. per annum furnish the best climatic conditions. The risk of frost damage while the trees are in blossom is always a serious one in Great Britain, and to avoid this the configuration of the land should be carefully studied in order to avoid natural frost pockets. Other things being equal, high ground is always better than low ground, and the question of aspect should also receive consideration, for apples grown on a southerly or south-westerly slope are always better coloured than those on slopes with a northerly aspect.

Rootstocks—An apple tree is a composite organism in that it usually consists of the variety—the scion—grafted or budded on to a root system—the stock. Much of the research work carried out in recent years has dealt with the rootstock question, involving, as was ultimately found, not only the inherent characteristics of the stocks themselves, but their effect on the growth of the varieties propagated on them. Although the prepotency of the rootstock was no new idea (Thomas Hitt, writing in his "Treatise on Fruit Trees," published in 1768, notices it, and Thomas Rivers published some information on the subject in the last century), it was not until the East Malling and Long Ashton Research Stations commenced the systematic study of the question, about seventeen years ago, that detailed and valuable data became available. To-day apple trees may be grafted or budded on rootstocks to produce trees with markedly different characteristics. Stocks not only affect the growth and, consequently, the size of the tree, but its fruitfulness in its early period of life, the time of blossoming, the setting and subsequent colour and size of the fruit, and even its susceptibility to disease. Nevertheless, the rootstock effect is subject to variation induced by soil conditions. The chief value of this new knowledge lies in the fact that growers may now select trees for planting for a particular purpose, and choose stocks to suit the fruiting and growing characteristics of the various varieties. The rootstocks now recognized as capable of giving a range of tree growth suitable for all purposes are as follows:

1. Jaune de Metz, known as Malling Type IX., very dwarfing effect, even on good soil. Trees on this stock should not be planted on poor, light soil. It is suitable for small, quickly fruiting bush trees and cordons of all varieties, except those of weak growth habit (see below).

2. Doucin, known as Malling Type II., semi-dwarfing effect, and suitable for medium-sized, quick-fruiting, bush trees of varieties with a medium growth habit (see below).

FRUIT (*Continued*)—

3. Broad-leafed English Paradise, known as Malling Type I., suitable for large bush trees of vigorous varieties, and also for medium-sized bush trees of the weaker growing kinds (see below).

4. A group classed as very vigorous, which have replaced the old "free" or "crab" stock, and now known as Malling Types XII., XIII., XVI., and Long Ashton O.F. 5. These are suitable for large standard trees, and also for bush trees of some of the very weakest varieties.

All these rootstocks may be propagated vegetatively, thus ensuring uniformity of behaviour, which is almost impossible to obtain when seedling stocks are used.

The effect of rootstock on tree growth is not, however, independent of the relative vigour of the variety grown upon it, and, as was stated above, soil conditions constitute an additional factor influencing growth. When deciding the planting question, therefore, the prospective grower should consult local opinion or seek competent advice from his County Adviser.

Varieties—Varieties of apples having an established commercial value for cultivation in the British Isles are as follows:

Culinary	(1) Growth habit—strong	**Bramley's Seedling.**	Season, late.
		Newton Wonder.	Season, late.
		Annie Elizabeth.	Season, late.
	(2) Growth habit—medium	**Lord Derby.**	Season, mid.
		Prince Bismarck.	Season, late.
	(3) Growth habit—weak	**Early Victoria.**	Season, early.
		Grenadier.	Season, mid.
		Lane's Prince Albert.	Season, late.
		Stirling Castle.	Season, mid.
Dessert	(4) Growth habit—strong to medium	**Blenheim Orange.**	Season, late.
		Beauty of Bath.	Season, early.
	(5) Growth habit—medium	**James Grieve.**	Season, mid.
		Rival.	Season, mid.
		Worcester Pearmain.	Season, mid.
		Allington Pippin.	Season, mid.
		Ellison's Orange.	Season, late.
		Cox's Orange Pippin.	Season, late.

Laxton's Superb, a late dessert apple of recent introduction, is a promising addition, but it has yet to prove adequately its commercial value.

Pollination—Scientific investigation on the subject of pollination has been carried out in recent years by Crane at the John Innes Horticultural Institution. As a result, it has been definitely proved that our varieties of apples exhibit a varying capacity to set fruit with the aid of their own pollen, and some, notably Cox's Orange Pippin and Beauty of Bath, are quite unable to do this to any appreciable extent, and must be regarded as self-sterile. This work is of very considerable importance to the grower, and often serves as an adequate explanation of the unprofitable condition of some plantations. When planning new orchards and plantations, therefore, the grower should safeguard this aspect of production by avoiding planting large blocks of any one variety, and by interplanting two or more varieties

FRUIT (*Continued*)—

which flower together in such a way as to ensure adequate cross-pollination. The varieties which blossom more or less together are as follows:

Mid-season blossoming : **Bramley's Seedling, Grenadier, Early Victoria, James Grieve, Allington Pippin, Gladstone, Worcester Pearmain, Cox's Orange Pippin, Rival.**

Late blossoming : **Lane's Prince Albert, Newton Wonder, Lord Derby, Annie Elizabeth, Blenheim Orange.**

Any two, or for preference three, selected from the above groups, if grown together, should secure effective pollination. At the same time, growers should avoid planting too many varieties, and should endeavour rather to produce large quantities of a few well chosen varieties, and thus facilitate marketing and building up a trade. As examples, a specialist grower could lay out a mixed plantation of bush trees of Cox's Orange Pippin and Worcester Pearmain worked on Type II. root-stock, and planted at from 14 to 18 ft. square, which should give quick returns, and last in a profitable condition twenty years or more. On the other hand, a farmer possessing suitable land might lay down a valuable grass orchard of standard trees consisting of the three outstanding cooking apples—Bramley's Seedling, Newton Wonder, and Annie Elizabeth (with perhaps a sprinkling of Worcester Pearmain to assist the pollination of the Bramley's Seedling)—planted from 30 to 40 ft. square, and all worked on either of the very vigorous stocks, Types XII., XIII., XVI., and Long Ashton 5, or, failing these, seedling or "free" stocks, provided the trees are carefully selected in the nursery.

Planting—Enough has been said to indicate the advance which has been made in connection with the fundamentals of fruit growing, but the grower must still employ intelligence to protect his interests. When purchasing trees for planting he should go to a reliable nurseryman and avoid cheap, foreign trees, for a cheap tree is often a dear tree in the long run. When breaking up fresh land for planting it should be thoroughly done, ploughing deeply and moving the subsoil, for which steam tackle may be necessary. Lining-out, planting, and staking are all operations which should receive careful attention. No organic manure need be applied to the land at planting time, but if potash is deficient it should be applied before planting, and be repeated annually to maintain the supply. On the poorer soils after the first year a little nitrogenous fertilizer may be given. Mulching the surface of the soil around the trees will ward off drought effects and assist them to become established. (See Fruit Plants, Manuring of.)

With so many considerations to bear in mind, it is often difficult to decide at what distance to plant, especially in the case of bush trees. Rootstock effect, soil conditions, varietal behaviour, are a few of the points calling for careful appreciation. There is nothing to be gained by overcrowding the land with trees, and a good deal to be said in favour of plenty of space. Under average conditions the following will serve as a guide:

FRUIT (*Continued*)—

(*a*) Dwarf bush trees on Type IX. rootstock, on good land, 9 ft. square, giving 537 trees to the acre. Varieties suitable for this rootstock are those of medium and strong growth habit (see above).

(*b*) Semi-dwarf bush trees on Type II. rootstock, 15 ft. square, giving 193 trees to the acre. Varieties suitable for this stock are those of medium growth habit, but the same distance would suit the weak-growing varieties when worked on Type I., as similar trees would result.

(*c*) Large and vigorous bush trees or half standards on Type I. rootstock, 18 ft. square, giving 134 trees to the acre. This distance will suit the varieties of medium growth habit, but the strong-growing varieties are better at 20 ft., giving 108 trees to the acre. The same distance would suit the bush trees of the weakest varieties when on the very vigorous rootstocks.

(*d*) Large standard or half-standard trees on Types XII., XIII., XVI., Long Ashton 5, or "free" stocks, 30 ft. square, giving 48 trees to the acre. This distance will suit the varieties of strong and strong to medium growth habit, but on very good land standard trees of strong spreading varieties, such as Bramley's Seedling and Newton Wonder, may need a distance of 35 or 40 ft. square.

The annual routine care of apple orchards and plantations involves the important operations of cultivation, manuring, pruning, and maintaining the trees in a healthy condition. The manuring of fruit trees has been dealt with in the article entitled Fruit Plants, Manuring of. It will suffice to say here that bearing fruit trees require varying amounts of nitrogen, phosphates, and potash in readily available forms, according to the type of soil, climatic conditions, etc. In America, where this subject has received very close attention, it is significant that very large quantities of nitrogen in the form of nitrate of soda or sulphate of ammonia are applied to apple trees by the growers. In Great Britain, where rainfalls are uniformly higher, such heavy dressings of nitrogenous manures do not appear to be so necessary, but probably the trees are more often starved of this plant food than otherwise. Wallace, working at the Long Ashton Research Station, has also demonstrated the important part played by potash in the tree's nutrition, and in the quality of its fruit.

Pruning—Pruning is another subject that has received attention from scientific workers in recent years, and as a result our conceptions of the objects and effects of certain time-honoured practices have undergone a change. To-day the successful commercial apple grower realizes that while a certain amount of hard pruning is necessary in the first years of the tree's life to shape it and induce vigorous growth, thereafter, the knife must be used very carefully, and each variety must receive specialized attention and treatment. Again, pruning methods for large permanent standard trees will differ from the treatment necessary for bush trees. Even now it is not generally recognized that once they are shaped-out, standard trees should be left to grow and develop a fruitful condition, and the knife should be employed only for a little light tipping of leaders in the case of certain varieties, but principally for thinning out surplus growth and keeping the middle of the tree open.

In general, it should be borne in mind that hard, indiscriminate pruning, contrary to general belief, does not induce fruitfulness, but has the adverse effect in forcing the tree into growth. Pruning does,

FRUIT (*Continued*)—

however, promote size and quality in fruit, assists in strengthening the tree, and so maintains it in a healthy condition; in the case of bush and half-standard trees a judicious use of the knife is often very necessary. Above all, the trees should be kept open and uncrowded with branches, in order to promote a hygienic condition and facilitate spraying and thinning operations.

Thinning of the fruit is another operation which pays the grower to perform when the trees have set heavy crops, as it promotes both size and quality. There is nothing gained by allowing the trees to carry too much fruit, but rather the reverse.

Cider Apples—In recent years there has been a considerable increase in the consumption of cider, which is manufactured from the juice of apples. The demand for cider in Great Britain is rarely met by the produce of home orchards, and considerable quantities of both fruit and juice are imported from the Continent. The growing of cider apples is mainly confined to the west of England, where the cider apple orchard is often a feature of the ordinary farm, and in the counties of Devon, Somerset, and Cornwall most of the apple trees are cider varieties. The National Cider Institute, which is attached to the Long Ashton Research Station, near Bristol, has rendered considerable assistance to the English cider industry by its investigation of vintage varieties of apples, and by the dissemination of information on their propagation and general cultivation.

The high quality bottled ciders of commerce that have become so popular in recent years are carefully blended products derived from the juices of specially selected vintage apples, which are broadly divided into three categories, viz., sweets, bittersweets, and sharps. The chief vintage features of these groups are the varying amounts of sugars, acids, and tannin in the juices, which enable the cider manufacturer, by means of skilful blending, to produce either "dry" or "sweet" ciders of varying qualities as to "softness," flavour, and aroma. The point of importance to the cider apple grower is that the manufacturer must be able to secure regular and sufficient supplies of the various vintage types throughout the somewhat extended picking season. In other words, successful growers of vintage fruit must be in a position to offer a sufficiency of sweets, bittersweets, and sharps at the same period of the year. Anyone contemplating planting cider orchards cannot do better than to seek advice from the Research Station referred to above, or, if he should be living in a well-known cider-growing district, from his County Council's adviser, as it cannot be over-emphasized that there is a very considerable amount of valuable technical information now available.

Varieties—There are a great many varieties of cider apples, some of a widely established repute and others of local origin; the latter, owing to their suitability to localized types of soil, are often quite meritorious, and find a ready sale amongst the cider grinders. As in the case of culinary and dessert apples, however, there is a great advantage in the limitation of varieties.

FRUIT (*Continued*)—

Apart from the question of vintage quality, each variety must be considered from the points of view of growth and cropping powers, ability to resist disease, average size of fruit, and, especially, its suitability for the type of soil on which it is proposed to establish the orchard. Examples of good cropping and reputable varieties of cider apples which can be mentioned here are as follows (the category of the fruit is indicated in brackets):

Early Gathering—**Killerton Sweet** (sweet), **Knotted Kernel** (bittersweet), **Belle Norman** (bittersweet), **Blackwell Red** (sharp).

Mid-season Gathering—**Sweet Alford** (sweet), **Cummy Norman** (bittersweet), **New Foxwelp** (sharp), **Dymmock Red** (sharp).

Late Gathering—**Chisel Jersey** (bittersweet), **Strawberry Norman** (bittersweet), **Ponsford** (sharp), **Slack-ma-Girdle** (sweet).

The juice of some of the culinary and dessert varieties of apples, notably Bramley's Seedling and Worcester Pearmain, may also be made into ciders of a fair quality. These varieties are often purchased by the grinders and used for blending purposes.

Whilst the importance of blending was emphasized above, there are a few well-known varieties in existence which are capable of producing a cider of fairly good quality when used alone. Examples of these are **Eggleton Styre** (sweet) and **Kingston Black** (sharp), which possess a substantial amount of the tannin and other properties, that are features of the "bitter-sweet" class, to make a good cider. These two varieties might well be added to the list given above.

Although many of the cider apples appear to be able to set fruit with the aid of their own pollen, some of them are not so reliable and a few are completely self-sterile. The mixing of varieties is therefore desirable.

The varieties named should blossom more or less together in their different categories in a normal season, thus ensuring effective cross-pollination. It is important to mix the varieties, a row of each being a suitable method of laying out cider orchards; such a plan also facilitates the harvesting of the fruit.

Planting—A cider orchard should be laid out on lines similar to other orchards of standard apple trees. The trees, which should be propagated on the very vigorous types of stocks, or failing those "free" or crab stocks, should possess good heads at the time of planting, with straight, strong stems of at least 6 ft. to keep the branches out of reach of cattle. Newly planted trees will make slower progress when planted straight into grass, and although this system is much practised, a good orchard of well-grown trees will be secured much more quickly if the first eight or ten years of its life are passed under cultivated conditions.

The general management of a cider orchard should follow lines similar to those advised for other apple orchards. It cannot be too strongly urged that cider apples need just as much care and attention to keep them free of pests and diseases as other apples.

In the damper, more humid climate of the west of England the

FRUIT (*Continued*)—

trees are prone to become covered with moss, lichen, and other noxious growths if spraying is neglected. Money expended on keeping the trees clean and healthy will be well invested. The orchards should be closely grazed with sheep, poultry, or horned stock, and not allowed to mature hay crops. The stock should be withdrawn for the time being when the fruit is nearing maturity in order to save as much of the crop as possible. The fruit is usually shaken off the trees, but a proportion of the crops will usually mature early and drop off on to the grass.

Insect Pests and Fungus Disease—Control is a very important aspect of apple production, as its absence is the principal cause of the production of low-grade fruit; in most areas it is the most expensive item in the production costs. The important pests of the tree are Aphides, Winter Moths, Apple Sucker, and Blossom Weevil, which all feed on the growth, foliage, or blossoms, resulting either in defoliation, with its debilitating effect, or loss of crop.

Pests of the fruit of importance are Apple Sawfly, Codlin Moth and Capsid Bugs, which either destroy the apples or render them unsightly and unsaleable.

The most serious fungus diseases of the apple tree are Canker and Scab, both of which seriously affect its health if left unchecked. Scab is also the chief fungus disease affecting the fruit. Most of the pests and diseases of the apple are readily controllable, but Scab and Capsid offer some difficulty.

The past decade has witnessed a substantial improvement in marketing methods for home-grown apples, although it must be confessed that this was largely forced on growers by the overseas competition.

Grading, together with improved methods of packing, in which the non-returnable box package plays a part, has come to stay, as the grower has found that it pays. The application of the National Mark to apples has also helped the home grower to make progress. (See Marketing.)

REFERENCES.—R. G. Hatton, "Results of Researches on Fruit Tree Stocks," *J. Pom.*, vol. ii., No. 1, November, 1920; "The Influence of Different Root Stocks," *J. Pom.*, vol. vi., No. 1. M. B. Crane and others, "On Self-Sterility in Plums, Cherries, and Apples," *J. Pom.*, vol. i., pp. 1-19; vol. iii., pp. 67-84; vol. vi., pp. 157-66; and vol. vii., pp. 276-301. N. H. Grubb, "Apple Pruning: Summary of Deductions from Experiments at East Malling," *J. of the Kent Farmers' Union*, vol. xviii., No. 5, November, 1925.

(2) **The Pear** (*Pyrus communis*)—Although pears do not occupy so important a place as apples in our fruit supply, they are nevertheless very popular amongst all classes; the demand is always keen, and, it is safe to say, is greater than the supply. The return of imports shows a steadily progressive rise for several years past, and it is significant that for the year 1930 a total of 1,030,315 cwts., valued at £1,723,618, was imported. As in the case of apples, therefore, the cultivation of good market pears could safely be extended in Great Britain.

FRUIT (*Continued*)—

The Census of Production of 1925 gave the total number of pear trees, including perry pears, on commercial holdings in England and Wales at 1,976,460. The yield of fruit for that year was estimated at 83,000 cwts. of dessert and cooking pears and 17,000 cwts. of perry pears. In the same year a total of 587,056 cwts. of pears was imported. The average value of imported pears for the years 1925-26-27 was returned at £1,396,000, as compared with the average value of £323,000 for home-grown pears. The areas of production in Great Britain are similar to those for apples, Kent being much the largest producing county.

It must be stated that many existing pear trees are of the old-fashioned varieties, producing small, sweet pears of indifferent quality, with very limited capacities for keeping and travelling, and while these kinds often satisfy a local trade, but few find their way in any quantities on to the large distributing markets where pears of the better class are mostly in demand. During the last twenty-five years, however, home growers have found a very fine pear for market purposes in the variety **Conference.** A tree of this variety possesses all the desirable attributes of a commercial pear, *i.e.*, hardiness, adaptability to varying conditions of soil and climate, freedom from disease, self-fertility, and good cropping powers. The fruit travels well, will keep for a reasonable period before becoming over-ripe, and with care can be cold-stored for a certain length of time. Another noteworthy point about Conference is that it will develop a full crop of large-sized fruit without the assistance of thinning. It is undoubtedly the best commercial pear for the climatic conditions of the British Isles, which, as a general statement, cannot be regarded as ideal for pears as a class.

One other variety is worthy of special mention: **Doyenne du Comice** is the quality pear *par excellence* of Great Britain. It is held in high esteem by all lovers of pears, and commands a very high selling value on home markets. In contradistinction to Conference, however, this variety is more particular as to situation and soil conditions, is more susceptible to frost damage, and is regarded as self-sterile and therefore apt to set very poor crops where effective cross-pollination is not secured. Where specially favourable conditions are available Doyenne du Comice responds to careful cultivation, and the results obtained justify its inclusion in the market class.

The *Dessert Pears* of first-class quality, suitable for commercial purposes, may be set down as follows:

Margaret Marrilat. Season, September.
Beurre d'Amanlis. Season, September.
Dr. Jules Guyot. Season, September.
Conference. Season, October-November.
Louise Bonne of Jersey. Season, October.
Emile d'Heyst. Season, October-November.
Beurre Superfin. Season, October-November.
Doyenne du Comice. Season, November.
Glou Morceau. Season, December.

The best of the small, poorer quality pears, referred to above are **Jargonelle** (season, August), **Chalk** (season, October), **Hessle** (season

FRUIT (*Continued*)—

October). These pears will sell on the markets, provided they can be placed there in good condition.

Stewing Pears.—There is a market for stewing pears, and the best market variety is **Catillac,** which is in season from November until April. It does best when grown as a standard or half-standard on the free stock.

The pears mentioned above are the best that can be suggested for commercial growers in Great Britain. The better class of dessert pears are best grown on trees of the half-standard, pyramid, or bush shape, such trees lending themselves to the care and attention these varieties call for. The poorer quality dessert pears, and the stewing pears, may be grown as standards, either on grass or otherwise. **Conference** will do very well as a standard also.

Various aspects of rootstocks for pears and also of pollination have received attention from research workers. Although in the past pears have been occasionally budded or grafted on various species of *Pyrus*, such as the mountain ash and the service tree, it was commonly the practice to employ either the Quince or the "free stock," the latter, as in the case of apples, being simply a vague term for seedling pears raised from perry pears or wild forms. To begin with, the several forms of quince, which was regarded as the dwarfing rootstock, were specially studied at East Malling, and, as in the case of the "Paradise" stock for apples, a substantial range of variation and effect was brought to light. As a result of this investigation the true Angers Quince (known as Malling Type A) has been defined as the most suitable dwarfing rootstock for pears, with the Common Quince (Malling Type B) the second best. Both these stocks are in general use, and pear growers are recommended to stipulate that their bush and pyramid trees are propagated on such stocks, remembering that these are dwarfing in effect and promote a tendency to early fruiting.

Less progress has been made with the question of rootstocks for half-standard and standard trees, but this work is still proceeding. For the present, however, the grower must take trees on the "free" stock, in which case, of course, there is always an element of speculation.

Pears will do well on a wide range of soils, but a good medium loam, well drained, is the most suitable. Conference, however, will grow and crop well even on heavy clays, such as Boulder clay, provided it is well drained.

Bush and pyramid trees of all the dessert varieties named, except Conference, may be planted at 12 ft. square, giving 302 trees to the acre. Conference, which tends to spread, especially when loaded with fruit, is better at 18 ft. square, giving 134 trees to the acre. Half-standard and standard pear trees should be planted so as to provide not less than 24 ft. square per tree.

As mentioned above, the subject of pollination in pears has been investigated, and so far as the available information goes the position is similar to that of apples, viz., a varying amount of self-fertility and several cases of actual self-sterility. When planning the planting

FRUIT (*Continued*)—

of pears, therefore, growers should make allowance for this, and mix the varieties in such a way as to ensure effective cross-pollination.

The following information will serve as a guide:

Group I—Beaurre d'Amanlis and Beaurre Clairgeau are regarded as self-sterile, but their blossoming period coincides with that of Conference and Margaret Marrilat, both of which are partly self-fertile.

Group II—Emile d'Heyst, Louise Bonne of Jersey, Catillac, are all self-sterile, but blossom together.

Group III—Doyenne du Comice and Glou Morceau are both self-sterile, but their blossoming period coincides with that of Dr. Jules Guyot and Hessle, both of which, however, are only very slightly self-fertile.

Perry Pears—Although not so popular generally as cider, an increasing interest is being shown by the public in perry as a beverage, and its consumption is not by any means exclusively confined to the famous perry districts of the West Midlands.

As in the case of cider apples, the perry pears exhibit a wide range of character as to their juices, which in turn affects the quality of the perry manufactured from them. It is stated that the most useful pears for perry making are those possessing some degree of astringency, coupled with a fair amount of sugar content. Many perry pears will not keep long enough, after reaching maturity, to enable them to be gathered and conveyed to the factory. Such varieties are useless except for grinding on the farm for home-made perry. The gathering season for perry pears, as in the case of apples, is spread over a lengthy period. Grinding usually commences about mid-September.

Recommended varieties are as follows:

Early.	*Mid-Season.*	*Late.*
Oldfield.	**Blakeney Red.**	**Aylton Red.**
Tayton Squash.	**Huffcap** (sweet forms).	**Winnals Longland.**
Moorcroft.	**White Bache.**	**Red Longland.**

All perry pears are of vigorous growth and usually make large, tall trees, more upright than spreading in growth habit. Only the vigorous or "free" root stocks are employed for propagation, and it is customary to start the head of the tree about 4 or 5 ft. from ground level. About 24 ft. apart is a suitable distance for the trees. A perry orchard is managed on lines similar to cider apple orchards. Owing to the great size and height of the trees, difficulty is sometimes experienced in carrying out spraying operations, but this work should not be neglected.

The pests and diseases of the pear are not nearly so numerous as those of the apple, but there are enough to require the grower to maintain constant watchfulness against their ravages. As with apples, Aphides and Winter Moths attack and defoliate the trees, but Capsid Bugs leave both trees and fruit alone. An additional pest of importance, however, the Pear Midge, infests the fruit, and can cause considerable loss. The Pear Scab fungus, not identical with, but closely allied to, the Apple Scab fungus attacks both foliage and

FRUIT (*Continued*)—

fruit. It is the most serious obstruction in the production of fruit of high quality, but it is capable of being adequately controlled.

Pears, like apples, pay well for careful grading and packing, and standards set up under the National Mark scheme may be adopted for this fruit.

To close this account it is necessary to issue a warning that the pear is, perhaps, the most speculative of the fruits grown commercially out-of-doors in Great Britain. This is due chiefly to the risk of frost damage, the blossoming period being very early in the spring, and considerably before that of apples. The success of Conference as a market pear is largely attributable to its hardy constitution and ability to resist the effect of frost. Growers may mitigate this element of risk by selecting sites calculated to give the maximum protection from frost.

References.—R. G. Hatton, "The Behaviour of Certain Pears on Various Quince Rootstocks," *J. Pom.*, vol. vii., No. 3, 1928.

SOFT FRUITS—A term applied to a group of cultivated fruits which are produced on plants, bushes, or canes. In Great Britain the term is usually held to embrace strawberries, currants, raspberries, gooseberries, blackberries, and loganberries. Almost all the supplies of soft fruits consumed in a fresh state are drawn from home growers, only those required for preserving purposes being augmented from the Continent. The demand is, therefore, a fairly steady one, and only in recent years has the production of black-currants shown a tendency to overtake the demand, but that may be due to faulty marketing facilities. On the other hand, the growing of soft fruits is an expensive business, and growers require to keep down production costs as much as possible. To this end demonstration work has shown that soft fruit plantations can, and should be laid out with a view to making the fullest use of motor or horse labour. Hand labour should be reduced to a minimum as it is expensive.

The expenses of gathering and marketing soft fruit crops are also very high, largely because hand labour for picking and handling has to be utilized. As an illustration of this, the estimated cost in Norfolk of cultivating, with horse labour, an acre of black currants, including land charges, soil working, pruning and spraying, and all manures, is approximately £18, and the cost of picking, packing, transport, and selling a ton of currants is approximately £15. Horse labour, then, will reduce considerably the production costs, and intending growers should have in mind, when selecting localities, that they must depend on hand labour for picking, and this is usually supplied by women and children. The transport factor in the selling costs should also be borne in mind, and reasonable accessibility to a station on a main line possessing a good service to the London, midland, and northern markets is a very distinct advantage.

Finally, as regards the future, it cannot be said that the production of soft fruits has yet overtaken the demand, and a better marketing

FRUIT (*Continued*)—

organization should develop the field of consumption. Scientific research, too, has overcome many of the difficulties which a decade ago loomed so menacingly, and there is accordingly a stronger feeling of confidence in the outlook.

Mention should also be made of the notable advance which the home-canning industry has made in recent years. The demand for strawberries, raspberries, and loganberries for canning at present far exceeds the supply, and home growers undoubtedly possess in this new industry an important additional market for their produce. On the other hand, if canning is to be successfully established in this country, there must be large and continuous supplies of fruit of the varieties most suitable for the purpose grown in localities contiguous to the factories. (See Preservation, Fruits and Vegetables.)

The great bush fruit growing areas of England are the Wisbech district on the Marine Silts, the west Cambridge district on the Greensand, the east Norfolk district on the sandy loams of the Norfolk Crag, the Kent districts on the Greensands and Woolwich, Oldhaven and Thanet Sands, and the south Hampshire district on the warm, early beds of Bagshot and other Sands. There are also scattered areas in the west Midlands on the Old Red Sandstone and Lias Beds of lighter texture.

For a general consideration of problems of manuring see Fruit Plants, Manuring of.

Blackberry (*Rubus* spp.)—Of late years increasing attention has been paid by fruit growers to the cultivation of blackberries for market. The fruit of the cultivated blackberry is large and attractive, and always appears to be readily saleable. It is, in some respects, more satisfactory to grow than either loganberries or raspberries, as the fruit, being firmer, travels in better condition; for the same reason the crops are not so liable to suffer from the effect of wet weather. There is no doubt that the blackberry is a profitable soft fruit crop when well-managed and cultivated on proper lines.

There are many forms of cultivated blackberries, some of which are regarded as hybrids and others as natural species. The variety most grown in the British Isles is the **American Cut Leaf** (*Rubus laciniatus*), which makes very vigorous growth and crops heavily, as much as 5 tons per acre having been recorded. It appears to be the best variety for market growing. Other good forms are **Himalaya Berry** and **Lowberry,** and **Kings Acre Berry.**

It might also be mentioned that hybridists in both England and the United States have experimented with crossing the loganberry and varieties of raspberry. Several of the hybrid products are in cultivation, but as the fruit is usually of the same colour as the parents they are hardly in the category of blackberries. Notable forms are the **Newberry,** the **Laxtonberry,** and the **Phenomenal Berry.** This fruit possesses more of the flavour of the raspberry than the loganberry, but in growth-habit and foliage resembles it closely.

FRUIT (*Continued*)—

Cultivated blackberries will succeed on almost all the types of soil that are suitable for fruit, but a light loam appears to suit them best. Even on poor, sandy soils the crop succeeds quite well.

Blackberries are propagated by layering in a manner similar to that adopted for loganberries, but owing to the brittle nature of the roots they do not transplant so readily, and losses are easily incurred when developing new plantations. For this reason, growers frequently root the plants in small boxes, chip punnets, etc., and the whole ball of roots is thus planted in the prepared holes without damage. As in the case of loganberries, it is the little additional care at planting time that makes for success.

Blackberries are also planted out and trained on lines similar to loganberries, *i.e.*, on post and wire fences formed about 6 ft. asunder with the plants set at about 8 ft. apart. Training is an expensive item in the production costs, but apart from this and the ordinary work of cultivation and manuring there is no money to be laid out for elaborate spraying schemes for controlling pests and diseases such as exists with so many of the other fruit crops. Fruit growers, therefore, might do well to turn their attention to the cultivated blackberry. Unfortunately the fruit has no canning value, and for this purpose the wild form of blackberry gathered from hedgerows is regarded as a superior form.

Currant, Black (*Ribes nigrum*)—As the result of persistent research work, the black currant has re-established itself as one of the most successful bush fruits of the British Isles. The great scourge of this crop, the "bigbud" mite, is now effectively controlled, and "reversion," evidently a virus disease, and one of considerable significance, is now definitely recognizable, and can be controlled by rogueing. Moreover, the fact that the "bigbud" mite is a "carrier" of the "reversion" virus has been established, so the control of the first-named has a reactive effect on the other. Research workers have also dealt with the problem of nomenclature, as, in common with most of the bush fruits, it was found that more names existed than distinct varieties. As a result, the black currants, with the exception of a few very promising new varieties, may be classified into four distinct groups or types regardless of name, a very welcome improvement on the condition existing a few years ago (R. G. Hatton, "Black Currant Varieties: A Method of Classification," *J.Pom.*, vol. i., Nos. 2 and 3).

The approximate acreage of black currants in England in 1929 was 13,664. The chief centres of production are east Norfolk, Cambridgeshire, Kent, and the west Midlands, but east Norfolk is by far the largest producing area, both the soil and climate being especially suitable.

Soil and Situation.—Any soil if of good depth and well drained, but retentive of moisture, will suit this crop, but a good loam on the heavy side will suit best of all. Black currants suffer from lack of moisture at the roots, but these conditions can be remedied by mulching and cultivation. The site chosen for the crop must be as free as

FRUIT (*Continued*)—

possible from the effect of frost, and a great danger arises through a too rapid thawing out after frost. For this reason a northern slope is often a more successful site than a south-eastern.

Varieties—Varieties are partial to districts and soil conditions. The type groups referred to are **Baldwin, French Black, Victoria** or **Goliath,** and **Boskoop Giant,** and the strains and selections of these types are well known. **Carter's Champion** and **Blacksmith** are unclassified varieties. Of the newer distinct varieties, **Davison's 8, Westwick No. 7,** and **Daniel's September** (a very late variety) are the most promising. The growers must find out which of these types and varieties are likely to suit local conditions of soil and climate. **Baldwin** is the weakest grower. In any case, strain in black currants is of great importance, and a new grower must start with a good strain carefully selected from *fruiting* bushes, and thoroughly rogued for reversion. The Ministry of Agriculture's scheme of certification is of great service in this connection. Growers raising their own bushes find that steeping the cuttings in cold water for three days before planting greatly reduces the risk of "bigbud" infection.

Planting—The land should be prepared thoroughly by ploughing and subsoiling, and apply a heavy dressing (twenty loads to the acre) of farmyard manure. The best aged bushes to plant are yearlings, *i.e.*, a bush grown from a cutting in the nursery bed for one year, but two-year-old bushes may also be used. The planting should be arranged so that horse labour may be used for cultivating between the rows, and for carting manure. Suitable distances are 4 ft. from bush to bush, and 7 or 8 ft. from row to row according to the type selected.

Cultivation—The annual cultivation consists of shallow horse-hoeing to keep down the weeds and to preserve the tilth; an annual application in the autumn, following the pruning, of from fifteen to twenty loads of farmyard or pigsty manure which is ploughed in. The ploughing is carried up to the rows, leaving an open furrow in the centre to take off surplus water. A little hand-hoeing round the base of the bushes may be necessary during the summer.

Pruning consists of thinning out the old wood to promote growth of young wood which bears the fruit. Skilful pruning, plus good cultivation will always maintain a constant supply of new wood. The bushes should be kept open and not crowded.

Reversion must be carefully regarded, and every year as soon as the shoots have made five or six new leaves, and in any case not later than July 7, the plantation should be gone over carefully, at least twice, and all infected bushes should be marked for immediate destruction. The grower must learn to detect "reversion" from the appearance of the foliage, and concentrate on keeping his plantation free (R. G. Hatton, J. Amos, R. C. Knight, and A. M. Massie, "Reversion in Black Currants: Its Causes and Eradication," *Ann. Rept. East Malling Res. Stat.*, May, 1928).

The fruit is usually marketed in 4 lb. chips and 24 lb. half-sieves. A good sample may go in 2 lb. chips. The pickers require careful supervision to ensure against damage to the bushes by breaking and

FRUIT (*Continued*)—

cracking young shoots and spurs which should be the fruit bearers of the following year. The fruit should never be picked when it is wet. From 3 to 4 tons per acre is reckoned a good crop.

Currant, Red (*Ribes rubrum*), *R. vulgare, R. patræum*—The demand for red currants is not quite so ready as for black currants, and their production is consequently more limited. Nevertheless, the reds, when well grown, are generally profitable, and unlike the remainder of the bush fruits, there is no serious pest or disease to trouble the grower.

The acreage of red currants in 1929 was returned at 4,431, and the chief centres of production are Kent, the Wisbech district, west Cambridgeshire, and east Norfolk.

Soil and Situation—The red currants do well on a variety of soils, but a sandy or gravelly loam appears to suit them best. As in the case of gooseberries, they can be grown beneath the shade of "top" fruit, and so constitute a useful bush fruit for working into a scheme of mixed fruit plantation. If anything they appear to prefer the shelter those conditions afford, as in open situations serious damage is often inflicted by winds.

Varieties—Good commercial varieties are **Fay's Prolific** (Syn. **Comet**), **Raby Castle, New Red Dutch,** and **Laxton's Perfection.**

Planting and Pruning—Two-year-old bushes are usually planted from 5 to 6 ft. apart with 6 or 7 ft. between the rows.

As red currants. in contradistinction to blacks, produce fruit on the old wood, pruning must be directed towards the production of fruit spurs on the main framework of the bush. This necessitates the removal of most of the current year's wood every winter, and it will also help if the new lateral growths are completely severed some 6 ins. from their base about August each year.

The fruit is marketed in 4 lb. chips, 14 lb. pecks, and 24 lb. half-sieves. One advantage of the red currant is that it will "hang" after ripening longer than any other bush fruit without taking harm.

Currant, White (*Ribes rubrum alba*)—The white currant is the third of the three distinct types of currants in cultivation, but although common in private gardens, where it is usually grown for dessert purposes, it has very little value as a commercial crop, and is not grown to any appreciable extent for market.

Gooseberries (*Ribes Grossularia*)—Gooseberries are a consistently profitable bush fruit, as, although prices tend to rule low, good cultivation can usually ensure an average heavy yield of fruit. The American Gooseberry Mildew disease, which at one time threatened to wipe out the crop as a commercial undertaking, is now susceptible to a substantial measure of control.

In 1929, the total acreage of gooseberries grown in England was returned at 18,833, the chief centres of production being the Cambridge and Wisbech districts, the west Midlands, and the fruit-growing districts of Kent. The Wisbech and Kentish districts are probably the largest producers; next in importance is the Evesham district of the west Midlands.

FRUIT (*Continued*)—

Soil and Situation—Gooseberries prefer a good, stiff, well-drained loam. On the lighter, sandier soils a shortage of potash, normally betrayed by the scorching or discoloration of the foliage, may make itself felt, and must be adjusted. The bushes are at home beneath the shade of top fruit, such as apples and plums, but are equally, if not more at home in the open. They are not nearly so liable to frost damage as black currants.

Varieties suitable for market growing are **Whinham's Industry, Lancashire Lad, Careless,** and **Crown Bob. The Leveller,** a superb dessert variety, is also grown for a special and rather limited trade in ripe fruit. Varieties favour different localities, a point to be borne in mind.

Planting—In common with other bush fruits, gooseberries respond best to applications of farmyard or pigsty manure. Ten to fifteen loads per acre, per annum, should be given to ensure good crops, and any deficiency in the supply of organic manure may be made up with fertilizers at the rate of 6 cwts. bone meal, 2 cwts. sulphate of potash, and 1½ cwts. sulphate of ammonia per acre. Two-year-old bushes should always be planted; either the "leg" or "stool" type of bush being suitable. The "leg" type of bush will, on the whole, give better quality fruit, and is easier to prune and maintain. Planting should be from 4 to 6 ft. from bush to bush, and, to allow of horse labour, either 7 or 8 ft. from row to row.

Pruning consists of thinning out the weak wood, and by use of the knife encouraging the production of spurs on the younger wood which always produces the best fruit. Tipping of the leading shoots should not be practised unless it is necessary to remove diseased wood.

Cultivation consists of an annual autumn ploughing, after the manure has been applied, and summer horse hoeing to keep down weeds and provide tilth. The important matter is to watch for symptoms of potash shortage, usually a discoloration of the leaves, and make good the deficiency with suitable dressings of sulphate of potash.

The fruit is marketed in 24 lb. half-sieves.

Loganberry (*Rubus vitifolius* var.)—Once thought to be the hybrid production of a cross between the Californian blackberry and the raspberry, but now regarded as a "sport" variety of that blackberry, *Rubus vitifolius*, this fruit has taken an important place amongst the English bush fruits, and constitutes a profitable market crop when successfully grown. The English loganberry possesses a more piquant flavour than the Continental fruit, and on account of this feature the demand for canning in recent years has exceeded the supply. The cultivation of this fruit may therefore safely be extended.

Soil and Situation—The conditions suitable for raspberries will suit loganberries, and even heavy clay loams, provided they are well-drained, will suit them. Land for loganberries needs very careful preparation. It should be subsoiled at the final ploughing, and from twenty to thirty loads of manure will be necessary to give the plants

FRUIT (*Continued*)—

a good start. The chief trouble in cultivating this crop is to get the stools well established, and no pains should be spared to obtain this.

Planting—Loganberry plants are normally tip-rooted yearling canes —that is, grown for one year after the tip was rooted. The planting method depends on the scheme of training to be adopted. There are two methods open to the grower. One is to set the plants out on the square at 6 ft. apart each way and train the canes in an upright position on poles. The other consists of setting the plants out in rows and training them fan-wise to a post-and-wire fencing, which should be strongly constructed. Against this support the plants are set out at from 6 to 10 ft. apart, with 6 or 7 ft. between the rows.

The cultivation is similar to that for raspberries, avoiding deep working and applying plenty of organic manure to encourage cane growth. All old canes should be removed as soon as fruiting is completed.

The fruit requires careful handling to avoid bruising, especially if required for canning purposes. It is marketed on the same lines as described for raspberries. A good crop ranges from 3 to 4 tons per acre.

Raspberry (*Rubus Idæus*), **red and yellow types**—In recent years successful raspberry growing has become more difficult, chiefly owing to the increase in the number of obscure diseases. Research work has, however, thrown considerable light on a good many of these problems, and the position is now more encouraging, whilst it has also been instrumental in clearing up the difficulties surrounding the problem of nomenclature (N. H. Grubb, "Commercial Raspberries and their Classification," *J. Pom. and Hort. Sci.*, vol. iii., No. 1, 1922). The outlook for cultivation of this crop is therefore a bright one. Only the red type is grown extensively on a commercial scale.

The total acreage of raspberries in England in 1929 was returned at 6,008. The chief centres of production are east Norfolk, the Wisbech and Cambridge districts, and Kent.

Soil and Situation—A fairly light, free-working loam of good depth suits raspberries best, and the situation should be as sheltered as possible, for the crop is very susceptible to wind damage. The land devoted to this crop should always be well-drained, and well-ploughed and subsoiled before planting. An application of farmyard or pigsty manure at the rate of twenty loads to the acre will give the plantation a good start, and on soil of average quality keep it going for two or three years. Subsequently, from ten to fifteen loads of manure every year at ploughing time will be necessary to keep the cane growth vigorous. If cane growth is weak, the addition of fertilizers (6 cwts. bone meal, 2 cwts. sulphate of potash, and 1½ cwts. sulphate of ammonia to the acre) will help, while the quality of the fruit will also be improved. The fertilizers should be applied in early spring and cultivated in.

Planting—The canes are planted in rows 6 or 7 ft. apart, and 1 ft. from cane to cane. This setting out will allow of horse labour being used for cultivating the crop. The rows of canes may be tied to wires strained on posts inserted about 20 yards apart, or be left free; the

FRUIT (*Continued*)—

former method is the best, especially in exposed situations. String may also be used in conjunction with the posts and wire to give support to the fruiting canes.

Cultivation consists of frequent horse-hoeings during the spring and early summer to maintain a surface tilth, but the work must be shallow to avoid damage to the fibrous roots. In the autumn the manure should be laid along the rows and the land given a shallow ploughing or forking, always ploughing up to the rows.

Varieties—Profitable varieties, all red types, are **Lloyd George, Pynes Royal, Red Cross, Baumforth Seedling B, Norwich Wonder, Hornet D,** and **Hornet E.** When purchasing stock, take great care to ensure that it is substantially free from disease, especially Mosaic (one of the Virus Diseases) and Blue Stripe Wilt (*Verticillium Dahliæ*).

Pruning—Consists of removing all old canes as soon as possible after fruiting and tipping the new canes which are left. Tipping has been found to improve the size of the fruit, but the ripening is somewhat delayed.

The fruit is marketed according to its quality and the demand in 1 lb. punnets, 2 lb. and 4 lb. chips for dessert and household purposes, and in ¼ cwt. and ½ cwt. tubs for jam makers. It should never be picked when wet. The crop may range from 2 to 4 tons per acre; less than this may be regarded as poor.

Strawberry (*Fragaria* spp.)—The production of strawberries for market is no longer a simple undertaking. Owing to the very marked falling off in vigour, or degeneration, of stocks and the alleged effect of diseases and pests, a lack of confidence in the crop has arisen. Given successful cultivation, however, the crop remains one of the most profitable of British bush fruits. For the guidance of prospective cultivators, the view is expressed that there is nothing fundamentally wrong except the lack of vigour in the plant. This fact alone has led to minor ailments being represented as major ones, and their suspected influence will recede as rapidly as the vigour of the stocks is regained by careful selection and good cultural treatment. In this connection the Ministry of Agriculture's scheme of certified stocks is fundamentally sound, and growers should support both it and their own interests by purchasing certified stock only. Form 25 to 50 per cent. of ordinary bought-in stock may be quite worthless. Growers are advised after starting with certified stock to raise their own stock as far as possible. The beds from which stock is to be taken should be ruthlessly "rogued," destroying all weak plants, and all plants not true to type. The limitation of runners is impracticable for raising plants for fruiting, but for raising and improving the vigour of stock it is certainly worth practising.

Although the cultivation of strawberries has declined somewhat in recent years, the acreage of the crop in 1929 was returned at the total of 20,361. The chief producing areas are south Hampshire (around Botley), the Wisbech district, the Tamar Valley district in Somerset, Kent, and the Evesham district.

FRUIT (*Continued*)—

Soil and Situation—Strawberries succeed well on a wide range of land provided it is cool and free from water-logged conditions; the best soils are deep, fairly stiff loams, and the land should be fresh and not recently used for the same crop. In preparing land for the crop, deep ploughing, subsoiling if necessary, with an application of farmyard or stable manure at the rate of twenty loads or more to the acre, is vitally important. The situation should be an open one, avoiding frost pockets, as the risk from frost damage is very great.

Varieties—Good market varieties are **Royal Sovereign, Sir Joseph Paxton, Madam Lefebvre, Bedford Champion, King George, Madam Kooi, Jucunda, Tardive de Leopold,** and **Oberschlesien,** the last three being very promising varieties from the Continent, and are claimed to be highly suitable for canning. Varieties are partial to districts and soils. It is important to see that only plants from "maidens," *i.e.*, one-year-old plants, are used when forming a new plantation.

Planting—The plants should be 12 or 15 ins. apart, and from 2 to 3 ft. from row to row. Planting should be done as soon after August as possible, according to local climatic conditions, and in no case later than the end of October. Early planting is one of the secrets of success. To guard against aphis attack, all plants should be dipped in nicotine solution before being planted.

Cultivation—It is very essential to ensure careful cultivation. To avoid damage to the plants, it is preferable that all hoeing should be done by hand, and great care should be taken to avoid drawing the soil away from the plants. Exposure of the "crown" is a contributory cause of failure. The crop will respond to an annual dressing of fertilizers as for raspberries (*q.v.*). Market plantations should always be "strawed," using barley or oat straw whenever possible.

The fruit is marketed in 1 lb. punnets, 2 and 4 lb. chips, and 14 lb. pecks, and where grading is practised, it is found to pay. A crop may range from 1 to 4 tons per acre, but 2 tons at least is necessary to leave a margin of profit. A crop of 4 tons is regarded as very good.

REFERENCES.—L. N. Staniland, E. T. Mann, and E. Ball, "Strawberry Investigations at Long Ashton," *J. Min. Agric.*, September and October, 1927; L. N. Staniland, *Ann. Rept. Long Ashton Res. Stat.*, 1928.

STONE FRUITS—The stone fruits of commerce comprise the plums, green gages, damsons, cherries, apricots, and peaches. The climate of Great Britain is too rigorous for the general cultivation out of doors of apricots and peaches, and although limited quantities are grown as wall-fruit in sheltered gardens and under glass, the bulk of the supplies of these fruits reach the markets of Britain from Southern Europe and South Africa. Vast quantities of peaches and apricots are imported, both as dried and canned fruit, principally drawn from the orchards of South Africa, Australia, and the United States. Outdoor peaches are a great feature of some of the fruit belts of the United States and Canada. The dried prune, of which enormous quantities are consumed every year in Great Britain, is a species of plum grown principally in

FRUIT (*Continued*)—

California and Southern Europe, but in recent years its cultivation has extended to South Africa and Australia.

(1) **The Plum** (*Prunus domestica*)—During the past twenty years the cultivation of the plum in Great Britain has undergone considerable extension, and in some respects this crop has been more profitable than apples. But plums, when ripe, are so perishable in character, and call for such prompt and careful methods in handling and marketing, that the risk of loss is very much greater than with apples. Also, as a class, plums are capable of bearing very heavy crops, and in years when there are large, abnormal yields of fruit the markets are apt to become glutted, and growers suffer a repercussion in the shape of low prices. Such a plum season was experienced in 1930, when many hundreds of acres bore crops averaging a hundredweight per tree, and many plantations averaged as much as 2 cwts. per tree. There is a divergency of opinion as to the cause of gluts of plums, but with a consuming population of over 40,000,000 it is difficult to appreciate the view that over-production is a contributory cause. It might reasonably be suggested that faulty methods of distribution and marketing, bearing in mind the special nature of the crop, are more often largely to blame. The home-canning industry is now showing a rapid development, and should provide a further outlet for the plum crop. Certain varieties of plums are also utilized to a very large extent by jam makers. (See Preservation, Fruit and Vegetables.)

The Census of Production of 1925 gave a total number of 5,104,500 plum trees, including greengages and damsons, on commercial holdings in England and Wales, and the yield of fruit for that year was estimated at 805,000 cwts. In the same year plums were imported to a total of 507,414 cwts. The average annual value of home-grown plums for the years 1925-26-27 was estimated at £1,223,000, and of imported plums, £955,000. The chief plum-producing areas of Great Britain are Kent and the west Midlands (Gloucester, Hereford, and Worcester), but other important centres are Middlesex, Cambridge, Isle of Ely, Huntingdon, and Essex.

It was remarked above that plums have tended to be more profitable than apples. This is due chiefly to the more regular productivity of the trees, which in its turn is accounted for by the more effective control growers can now exercise over the pest and diseases to which the plum is liable. The chief insect enemies of the plum are the defoliating caterpillars of the Winter Moths and the Aphides. The new egg-killing winter washes made from tar distillates, etc., have provided the plum grower with a reliable and perfect control of these pests. (See Insecticides and Fungicides.) A feature of nearly all forms of persistent pest and disease attack is that the effect tends to become cumulative, and the result of non-control is not only annual losses of crop yields, but a far-reaching debilitating effect which is reflected in the reduced cropping powers of the trees in successive years. The most serious fungus disease of plums, Silver Leaf (*Stereum purpureum*), which once threatened to wipe out completely some of the more susceptible varieties,

FRUIT (*Continued*)—

such as **Victoria,** has been the subject of a prolonged investigation by scientific workers, with the result that methods of combating it are known and can be practised to an extent sufficient to give the grower a substantial amount of protection from the ravages of the disease. Under suitable conditions of soil and climate, and with a judicious selection of varieties, therefore, plums should continue to be a profitable fruit crop, and, moreover, one especially suitable for small growers, where the trees may be grown in conjunction with soft fruits. A noteworthy point with plums is that in general the trees take less time to come into a profitable bearing condition than apples or pears.

Soils and Situation—Plums are more at home on the heavier types of soil. The soils of great plum-growing districts—the marly clay loams of Worcestershire, the boulder and other clays of Cambridgeshire and Huntingdonshire, and the heavy silts of the Wisbech district—all testify to this. The drainage, however, must always be good, as water-logging predisposes the trees to "die back" and other diseases of a functional nature. Owing to the earliness of the blossoming period, high land is always preferable to low-lying land, and actual aspect is, perhaps, less important, but protection from bleak north and east winds is very desirable.

Labour for picking the fruit is an important consideration with fruit crops of this type, and as far as possible plantations should be located where there is a plentiful supply of casual labour.

Varieties—There is a good range of established market varieties, and the plum grower should endeavour to select a list which will give him an extended season of cropping, thereby enabling him to maintain a regular supply to the markets. The following is a suitable list, as a general recommendation, in their order of cropping: **Rivers's Early Prolific, Czar, Pershore** (syn., **Yellow Egg**), **Purple Pershore** (syn., **Purple Egg**), **Victoria, Pond's Seedling, Monarch, President.**

In addition to the foregoing there are several noteworthy plums of established commercial value which, as was once the case with the Pershore, are of a somewhat localized nature, but of which the cultivation is gradually extending. The best of these are: **Kentish Bush** (Kent), **Blaisdon Red** (Gloucestershire), and **Wyedale** (Yorkshire), and it may be noted that they are especially suitable for grass orchards.

The pollination question is also important in the case of plums. Czar, Monarch, Pershore, Purple Pershore, Victoria, Kentish Bush, are regarded as self-fertile, and therefore are unlikely to be disappointing when planted in large blocks; but Rivers' Early Prolific, Pond's Seedling, and Wyedale are known to be either self-sterile or nearly so, and to ensure crops they must be planted with other varieties.

The natural growth habit of plums varies considerably, and apart from the pollination question, both air, circulation, and economy of spacing can be secured by interplanting the spreading varieties, such as Victoria, with those of more upright habit, such as Monarch, a good planting distance for half-standards—the best shaped tree for plums

FRUIT (*Continued*)—

on cultivated land—being 18 ft. square, giving 134 trees to the statute acre.

The pruning of plum trees is a simple matter, being concerned in the early years of the tree's life only with the formation of a well-shaped, evenly balanced tree, and, thereafter, with the maintenance of the tree in an open, airy condition and free from dead wood. Pruning, however, has this important aspect, that it is responsible for wounds being made on the trees through which the spores of the dreaded Silver Leaf fungus (*Stereum purpureum*) are able to enter. In this connection scientific investigation has demonstrated that plums may be pruned in August and early September without any harmful effects, since at this period the risk from silver leaf invasion is greatly minimized by reason of the tree's protective capacity, which disappears as the autumn advances.

Plums in common with most of the stone fruits are gross feeders, and require a plentiful supply of nitrogen. When the trees are in a full bearing condition an annual application of nitrate of soda or sulphate of ammonia, applied in March at the rate of 3 to 4 cwts. per acre, will be very beneficial. On cultivated land the fertilizer should be worked in with the first cultivation in the spring. Generally speaking, plums require more nitrogen than apples, and this is an important point too often ignored by growers. (See Fruit Plants, Manuring of.)

Plums are marketed in chip baskets of 12 lbs. net for the selected fruit, and wicker baskets (half sieves) of 40 lbs. net for the general grades. In the West Midlands the "pot," a large wicker basket holding 72 lbs. net, is very popular for the preserving plums.

In the case of fruit consigned to the markets, it pays to grade plums into two qualities.

In addition to the pests and diseases already touched upon, red spider, a debilitating foliage pest, and Brown Rot (wither tip), caused by *Monilia Cinerea*, should be mentioned. Aphides, of which three species infest plums, remain the most serious insect pests, and a winter spraying with a tar distillate should be included in every plum grower's programme. To avoid risk of infection all dead branches, tree trunks, etc., should be carefully gathered and burned every season, as it is on such material that the Silver Leaf fructifies and produces its spores.

(2) **The Gages** are a distinct group of plums, remarkable for their fine flavour, which appear to have been introduced into Great Britain from Italy (which is not regarded as their country of origin) more than 300 years ago. The members of this group appear to have enjoyed many names in each country to which they travelled, but they are supposed to owe their English name of Gage to Sir Thomas Gage, of Hengrave Hall, near Bury St. Edmunds, who obtained trees from France early in the eighteenth century. Although this type of plum must have been established in Great Britain at that time, probably under divers names, the name Gage has since been generally adopted

FRUIT (*Continued*)—

and still serves to-day. Their great popularity, both as dessert plums and when made into jam, probably accounts for their claim to recognition as commercial plums. The geographical range of cultivation of the **Green Gage,** the best known variety of Gage, has been somewhat restricted, however, due probably to its apparent preference for the heaviest types of soil, and for a dry, sunny climate. It is grown extensively in the eastern counties, where it thrives well on the heavier loams overlying the chalk, and on the Boulder, Oxford, and Kimmeridge clays when well-drained.

As might be anticipated with a fruit that has been established in Great Britain for several centuries, there are many forms of the Green Gage in existence. That known as the **Cambridgeshire Green Gage,** which makes a large, spreading tree, with fruit ripening about the middle of August, is a good market form. It shares with the Pershore, Kentish Bush, and Blaisdon Red Plums the merit that it can be grown on its own roots, and may, therefore, be freely propagated from suckers.

Evidence has been accumulated to support the view that while not in the category of completely self-sterile varieties better crops are secured when the Green Gage is interplanted with varieties such as Pershore and Rivers's Early, which bloom concurrently.

The Green Gage does well in grass orchards, but takes longer to come into full bearing condition than most of the plums.

(3) **The Damson** (*Prunus spinosa*)—This group of small, purplish-black, plum-like fruits is extremely popular with the public, and the rich flavour of damson jam makes a special appeal to all classes of consumers. The larger kinds are valuable also for canning and bottling. As in the case of the Green Gage, the Damson has been established in Great Britain for many centuries, and a result arising from this has been the appearance of local varieties specially adaptable for cultivation under localized conditions of soil and climate. Some of these local varieties, moreover, possess exceptional merit, and their more general cultivation is therefore extending.

Varieties—Those grown generally are **Merryweather** and **Farleigh** (*syn.*, **Crittenden, Cluster**), the latter being the most common variety, especially in Kent, where it originated. Valuable local varieties are **Shropshire Prune** (*syn.*, **Prune Damson, Damascene**), **Aylesbury Prune,** and **Bradley's King of the Damsons.** The first two varieties bear fruit larger than the ordinary run of damsons, and the last-named, which is a Kent variety, bears medium-sized fruit.

Most of the damsons make large spreading trees, and, with the exception of the Aylesbury Prune, which can be propagated from its own suckers, are budded on known rootstocks. Pollination appears to be of less importance in the case of damsons, and all the varieties mentioned are very prolific bearers in favourable seasons. The ripening season is generally late, extending from mid-September to early October.

Soil and situation preferments, together with cultivation, are similar

FRUIT (*Continued*)—

to those for plums. The damsons are equally at home on grass as on cultivated land. Kent is probably the largest damson-producing county.

(4) **Cherry** (*Prunus avium* and *P. Cerasus*)—**Introduction**—The cherry an exceedingly popular stone fruit, and as its production is somewhat limited, the supply very seldom exceeds the demand, and the prices realized are nearly always satisfactory.

Speaking broadly, there are two distinct groups of cherries, viz., the sweet cherries which constitute the dessert forms, and the sour cherries which are employed mainly for cooking. The sweet cherries are regarded as derived from *P. avium*, and the sour cherries from *P. Cerasus*. There is also a small intermediate group known as the Duke cherries which, while possessing a sharper, more acid flavour than the sweet cherries, are quite suitable for dessert when fully ripe, besides being excellent cooking cherries. The origin of this group is somewhat obscure, and although regarded by many authorities as derived from the crossing of *P. avium* and *P. Cerasus*, genetical research undertaken in recent years has indicated that the Duke cherries may be aberrant segregates of *P. avium* only.

There is an abundance of evidence pointing to the fact that the Cherry has been cultivated by man from the very earliest times. Its natural home appears to be Asia Minor, and history records how cherries were taken to Rome and thence to the British Isles during their occupation by the Romans. During Saxon times fruit growing in Britain appears to have fallen into neglect, but the Normans are said to have re-introduced cherries, and again, it is recorded that during the Tudor period, at the instigation of Henry VIII., cherries were "fetched out of Flanders" and planted in Kent. One result of this long association with man is that there are a great many varieties, particularly of the sweet cherry, in existence today. The Census of Production for 1925 gave a total number of 741,493 trees on commercial holdings in England and Wales, and the yield from these was estimated at 350,000 cwts. In the same year a total of 138,513 cwts. of cherries was imported into Great Britain. The average annual value of the home-grown cherries for the years 1925-26-27 was estimated at £750,000, and the average declared value of the imported cherries for the same period was £350,000.

Although not so important as the plum, it is clear from these figures that the cherry is a fruit of considerable economic importance. The chief areas of production are Kent (the cherry orchards of this county are world famous), Middlesex, Buckingham, and the west Midlands. Kent has by far the greatest number of cherry trees (in 1925 the figure was 455,624), where they thrive exceedingly well on the brick-earth overlying the Chalk in the Faversham and Sittingbourne districts, and on the Hythe Beds of the Lower Greensand in the Maidstone district. A noteworthy feature of the Kentish cherry orchards is that they are all under grass orchard conditions, which the trees are said to prefer. Under cultivated conditions in England cherry trees are said to be

FRUIT (*Continued*)—

more prone to a peculiar malady known as "gumming," and generally are less thrifty. This is in contradistinction to North American experience, where the cherry is nearly always grown under cultivation and is said to prefer these conditions. Probably the real explanation of the grass orchard of England must be sought in other directions, bearing in mind the difference in climatic and other conditions of the two continents.

Soil and Situation—The sweet cherries thrive best in light, well-drained soils, and even the lighter sands where sufficiently deep and well-drained will suit this class of cherry extremely well. The importance of good under-drainage is borne out by the fact that profitable cherry orchards are found in districts such as Kent, Buckingham, and parts of Norfolk, where the surface formations are underlaid by the chalk. In the west Midland districts somewhat similar soil conditions are encountered on the old Red Sandstone formations. It is noticeable, too, that the wild cherries of the woodlands are usually associated with such conditions, and where these trees are observed it is fairly certain that cherry orchards may be established with some degree of success. The actual presence of lime in the soil is not so important as was once thought.

Owing to the early period of the year at which cherries blossom, the site for orchards should be very carefully selected. Natural frost pockets and bleak, wind-swept situations should be avoided. The great danger at blossoming time arises from the risk of "frost scald," due to the sun coming suddenly on to the trees after a frosty night. For this reason orchards in undulating districts are safer if located on land with a south-west or north-west aspect, rather than on land sloping to the east or south-east. On the other hand, flat, open situations, where the air is likely to keep moving and not form cold, stagnant pools, appear to be quite as safe from the point of view of freedom from frost damage.

Varieties—It was remarked above that there are a great many varieties and sub-varieties in existence, and it is often a matter of difficulty for a planter to decide upon the best varieties to form a new orchard. The sweet cherries derived from *P. avium* are universally recognized as falling into two groups possessing somewhat distinct features: these are the Gean Cherries (the Guigne of the French), or Heart Cherries and the Bigarreaus. The first group includes both white and coloured varieties, the fruit usually being of medium size, round in shape, with a soft, tender, and juicy flesh. The second group also has both coloured and white varieties, but the size is generally larger, and the fruit bolder and more heart-shaped than the Geans. The flesh, the chief distinguishing feature of both groups, is firmer and of a crisper nature, and these cherries as a class hold the supreme place amongst the market varieties. Commercially "White"—a market term—is applied to all those cherries, other than the black, reddish-black or purplish-black varieties, which are usually of a pale yellow or amber colour flushed with red when ripe. Although many of

FRUIT (*Continued*)—

the white cherries such as Napoleon, a Bigarreau of superlative quality, are extremely popular with the public, it is generally recognized that the black cherries make the greatest appeal, and are consistently higher in selling value.

The confusion in nomenclature that has long existed amongst the cherries has been intensified by the practice of adopting local names for varieties of much wider use, the result being that well-known market varieties often appear under different names in different localities. Varieties may also have been deliberately renamed for ulterior motives; this has added further to a highly undesirable condition of affairs. When buying cherry trees for planting, therefore, the fruit grower cannot be too careful as to the source from which he obtains them. Only reliable firms of nurserymen should be selected, and, as an alternative, the grower may raise his own trees by propagating definitely known varieties of proved merit.

The following sweet cherries are especially selected for their reputation as profitable market varieties, and all of them are to be found in English cherry orchards.

(1) **Early Rivers.** An early black. Gean type. 2, 5, 6.
(2) **Governor Wood.** An early white. Heart type. 1, 13, 4, 12, 9, 5, 14.
(3) **Elton.** A mid-season white. Heart type. 13, 12, 5.
(4) **Knight's Early Black.** A mid-season black. Gean type. 2, 5, 11.
(5) **Frogmore Early.** A mid-season white. Bigarreau type. 1, 3, 13, 12, 2, 4, 8. (There are two Frogmores, this is the early one).
(6) **Waterloo.** A mid-season black. Gean type. 10, 2, 13, 17.
(7) **Noir de Guben.** A mid-season black. Bigarreau type. 1, 2, 5.
(8) **Bedford Prolific.** A mid-season black. Heart type. 3, 12, 2, 5, 11, 14.
(9) **Black Eagle.** A mid-season black. Heart type. 5, 11, 10.
(10) **Amber Heart** (*syn.*, **Kentish Bigarreau**). A mid-season white. Heart type. 11, 7.
(11) **Napoleon.** A late white. Bigarreau type. 1, 2, 4, 5, 11, 10.
(12) **Turk** (*syn.*, **Turkey Heart**). A late black. Bigarreau type. 13, 8, 6.
(13) **Emperor Francis.** A late black. Bigarreau type. 1, 3, 2, 12, 4, 8, 5.
(14) **Noble** (*syn.*, **Tradescant's Heart**). A late black. Heart type. 2, 13, 12, 8, 5.
(15) **Florence.** A late white. Bigarreau type. 10.
(16) **Roundell.** A late black. Bigarreau type. 13, 4, 10.

Other good varieties are: **Bigarreau de Schrecken, Noir de Schmidt, Jaboulay, Geant de Winkler,** and **Windsor.**

Napoleon is undoubtedly the finest white cherry in cultivation for market, and Waterloo, Roundell, and Early Rivers are fine examples of black cherries. While it is impossible to give a perfect

FRUIT (*Continued*)—

sequence of fruiting in the case of cherries—weather conditions and other seasonal factors affect this question—the grower should endeavour to obtain an extended picking season; in Great Britain this can normally extend from the end of June until early August.

Pollination—In the case of cherries the subject of effective pollination is even more important than in other stone and hard fruits dealt with in these articles. The reason for this is due partly to the fact, as scientific research carried out during the last twenty years has shown, that practically all the sweet cherries in general cultivation are self-sterile and totally unable to set fruits with the aid of their own pollen, and partly to the complicated nature of the pollination question itself. The latter aspect of the general problem turns on the discovery that, in contradistinction to other fruits—such as apples and pears—it is not sufficient to have different varieties blossoming together to ensure satisfactory cross-pollination, for care must be taken to ensure that compatible varieties are selected for planting together. Our knowledge of cherry pollination in Great Britain is due to the investigations of M. B. Crane, at the John Innes Horticultural Institution, and C. H. Hooper of Wye Agricultural College, the latter working for many years amongst the cherry orchards of Kent. To M. B. Crane cherry growers owe most of the information bearing on the question of incompatibility, or, in other words, the knowledge that certain varieties of sweet cherries are unable to effect cross-pollination with one another and are therefore intersterile. An example of this may be given by quoting Early Rivers, a fine market cherry universally grown, which being self-sterile would, however, still remain barren when planted with either Bedford Prolific, Black Eagle, or Knight's Early Black, despite the fact that their flowering period approximates, and *vice versa*. This is only one example of where the scientist has rendered assistance of a definitely practical nature to the fruit grower, and the special significance attached to this particular investigation lies in the fact that it has supplied a satisfactory explanation of the unfruitfulness of many existing cherry orchards. With the aid of this new knowledge growers are able to remedy such defects, and in many instances unproductive orchards have been turned into a profitable condition. To sum up the position, therefore, the grower of sweet cherries should select carefully the varieties he desires to grow, avoiding incompatibility, and choosing those which blossom as nearly as possible at the same date.

To make the subject of pollination in sweet cherries as clear as possible, the seventeen varieties quoted in this article are numbered. The numbers appearing after each variety refer to those which may be planted with it so as to ensure compatibility and at the same time secure effective cross-pollination, often in either direction. From such a list a selection of varieties may be made to form a productive and profitable cherry orchard.

The question of how best to arrange the varieties when planning cherry orchards is a controversial subject, but bearing in mind the

FRUIT (*Continued*)—

peculiar nature of the difficulty in the case of cherries, it is probably the safest plan, when a good number of varieties are to be grown, to alternate the two compatible varieties in the row. When planting only a few varieties the rows of mated varieties only might be alternated, a plan which would assist the work of picking. Hive bees as pollinating agents are of considerable service to cherry growers, and a few hives should always be kept in the orchards.

When attempting to restore to a fruitful condition orchards which are believed to be barren through lack of proper pollination, it is considered that the "heading off" and top-working of every third tree in every third row will produce effective results. Top-working will always give quicker results than the introduction of young trees.

Planting—The planting of cherry orchards should follow lines similar to those adopted for other large standard fruit trees, such as apples. Cherry trees should have stems of at least 6 ft. The rootstock on which the varieties are usually grafted or budded are the wild Sweet Cherry seedlings (*P. avium*) of the woods, which, however, lack uniformity in effect, etc. To remedy this the subject of stocks for sweet cherries has been studied at East Malling, and it was discovered that desirable cherry rootstocks, such as those of the apple and plum, may be propagated vegetatively from layers, and such layered stocks should be much more reliable. Cherries grow into immense trees under favourable conditions (it is recorded that one tree has borne a ton of fruit in the year), and the trees should accordingly be given plenty of space in which to develop. From 30 to 40 ft. (=about forty-eight trees per acre) from tree to tree should be about right, and the equilateral triangle system is, on the whole, the most satisfactory arrangement. Although the trees may be planted direct into existing grass land, they will thrive best and grow more quickly if planted on cultivated land, grassing down the orchard when it is about twelve years old. For this reason sweet cherries are often planted through a plantation of soft fruit which is ready for clearing about the time the cherries require grassing down.

It is important to stake all young cherry trees very firmly to avoid wind damage, and if the orchard is unprotected wire guards should be placed round each tree.

Sweet cherries, once the shape of the tree is secured, require very little pruning, and should be left to develop naturally. In established orchards the trees should be gone over during the month of September to remove dead wood, crossing branches, etc.

Another important aspect of cherry growing which should be mentioned is concerned with the ultimate grassing down of the orchard. Too often orchards are allowed to "fall down" to grass, which means that a large proportion of coarse herbage, besides perennial and other pernicious weeds, may be produced. To form a proper turfy sward, such as is the pride of the many Kent cherry growers, the land should be carefully cleaned and sown down with a selected mixture of fine grasses, to which a little genuine wild white clover may be added.

FRUIT (*Continued*)—

This method will soon produce a close compact turf providing a good "bite" for the sheep which should be used largely for grazing. In Kent the Romney Marsh or Kentish sheep are chiefly employed for grazing the cherry orchards, but any other type of good grazing sheep will do equally as well. The advantage of the Kentish sheep is that they are very hardy and scatter well when grazing. About ten sheep to the acre is the number usually employed, and the orchards should be only lightly stocked or completely rested during the winter months; they should never be permitted to grow crops of hay, since the trees are likely to suffer considerably from such a practice.

Sweet cherries are usually marketed in wicker half-sieves holding 24 lbs. net weight, but of late years the use of the 6 and 12 lb. chip basket and trays of 1 lb. punnets for the higher grade fruit has developed considerably. Cherries are now included in the National Mark scheme of marketing.

Birds are the chief pest of the sweet cherries, and unless the orchards are carefully watched from dawn to sunset during the ripening season much fruit will be lost. In wet seasons the fruit is liable to crack and spoil, and Brown Rot (*Monilia cinerea*) is a serious fungus disease affecting both trees and fruit during cold, damp weather. In addition to the Winter Moths, the larvæ of which attack cherries as well as apples and plums, the Black Cherry Aphis (*Myzus cerasi*) is often a serious pest, particularly of young trees.

The Duke Cherry—It was mentioned above that the Duke Cherries occupy a class falling between the Sweet and Sour classes. They are slightly subacid in flavour, and serve equally well for cooking and dessert purposes. The trees are neither so large nor so spreading as those of the sweet cherries, and may consequently be planted closer together. Also, they are not quite so intolerant of cultivated land as the sweet cherries, although the older trees appear to favour grassed conditions. As with the sweet cherries, self-sterility is a common attribute of the Dukes, but they cross-pollinate freely with sweet varieties, with which they should be planted to ensure full crops.

Good varieties of Duke Cherries are **May Duke** (early), **Arch-Duke** (mid-season), and **Late Duke** (late). May Duke is a very useful variety to grow, as it usually is the first of all the cherries to ripen in early June.

The Sour Cherry—The remaining class of the cherries is known as Sour, and not infrequently as Morello cherries; they constitute the market cooking cherries, but the fruit is also greatly in demand for the manufacture of cherry brandy. They resemble their wild progenitor, *P. Cerasus*, in making small, shrubby, rather pendulent trees, and so may be grown in cultivated plantations planted on lines similar to the plums, *i.e.*, about 18 ft. apart each way. They may be pruned rather hard, if it is necessary, to encourage the production of young fruiting wood (in this respect they differ from the sweet cherries which fruit on the older wood), but as a rule they grow quite freely if left unpruned and merely thinned.

FRUIT (*Continued*)—

Sour cherries differ from the sweet cherries in thriving well on a variety of types of soil provided there is plenty of depth and good drainage. Another good point is that the various varieties of this class are self-fertile, thus enabling large blocks of one variety to be planted.

Good market varieties of sour cherries are **Kentish Red** (mid-July), **Flemish Red** (end of July), and **Morello** (August). There are several forms of Morello in existence, and a good example should be sought for, as this variety is the best of the sour cherries, and commands a high price in the market.

REFERENCES.—A. H. Hoare, "The English Grass Orchard," E. Benn, Ltd., 1928; M. B. Crane and others on "Self Sterility in Plums, Cherries, and Apples," *J. of Pomology*, vol. i., pp. 1-19; vol. iii. pp. 67-84; *idem.*, "Self and Cross Sterility in Fruit Trees," *J. of Pomology*, vol. vi., pp. 157-66; C. H. Hooper, "Notes on the Pollination of Cherries applied to Commercial Cherry Growing," *J. of Pomology*, vol. iii., pp. 185-90.

INSECT PESTS OF FRUIT TREES AND BUSH FRUITS, CONTROL OF—Progressive fruit growers are now unanimous in their opinion that spraying provides an efficient means of insect pest control, and is consequently a very essential factor in successful fruit growing. Nevertheless, for various reasons, there is a great deal of unsatisfactory spraying carried out.

Diseases and insect pests of fruits vary in intensity from one year to another, but experience has shown that the most profitable procedure in dealing with them is to spray every year. A spray may have more effect in the year following than in the actual season of application, as any year's fruit buds are formed the previous summer.

In order that spraying shall give satisfactory results, it is primarily necessary that good trees should be planted approximately the right distance apart, and that they should be properly pruned and manured. There is a large acreage in this country in which the trees are planted much too closely to each other, and have also been allowed to grow too thick. Under these conditions the cost of spraying is too high and the returns from the fruit too low. In their present state such trees are not likely to show much profit to the grower, even when sprayed on the most up-to-date lines.

Egg-Killing Washes—The introduction from the Continent in 1923 of the so-called "tar oil" washes has effected a big change in the routine spraying of orchards; it is, indeed, the most important addition to our knowledge of the control of fruit pests for a very long time. The older types of winter washes, such as lime, lime sulphur, and caustic soda, were useful in cleaning trees, thus removing the hibernating quarters of certain pests, in killing some hibernating insects, and, under certain conditions, in reducing attacks of Aphis and Apple Sucker.

Tar oil washes possess these properties and, in addition, have been shown by careful experiments to be capable of killing the eggs of certain pests. In the short space of time since their introduction,

FRUIT (*Continued*)—

tar oil washes have almost entirely superseded the other winter washes.

Experiments by various workers have shown that when used commercially at a strength of 6 per cent., these washes will almost entirely prevent attacks of the Apple Sucker and Aphides on fruit trees and bushes of all kinds; the Apple Sucker is thus no longer a pest of trees which have been sprayed periodically with a tar distillate wash. Experiments have also shown that at a strength of 10 per cent., Winter Moth (*Cheimatobia brumata*) and Tortrix Caterpillars can be reduced by from 50 to 80 per cent., and Massee (*Fifteenth Ann. Rept. East Malling Res. Stat.*, 1927) has shown that Vapourer Moth eggs are destroyed by a $7\frac{1}{2}$ per cent. concentration.

On the other hand, certain insect and mite eggs, of which the most important are the eggs of the Fruit Tree Red Spider (*Oligonychus ulmi*, C. L. Koch), are not affected by these sprays at a 10 per cent. concentration. Massee has also shown that neither the eggs of the Lackey Moth nor of the Black Currant Gall Mite are affected by 10 per cent. of a tar oil wash. It is a noteworthy fact that "Red Spider" has become much worse on trees where tar oil washes have been used, and this is probably because these washes kill off predatory insects and mites which under natural conditions prey on the "Red Spider."

On the other hand, the gooseberry red spider (*Bryobia ribis*) can be controlled by using $7\frac{1}{2}$ per cent. of a tar oil wash.

There is no evidence that these washes reduce or increase Apple Scab (*Venturia inæqualis*) to any extent, but, indirectly, by reducing the attacks of Plum Aphis, it has a marked effect in reducing "Brown Rot" (*Sclerotinia cinerea*) of plums. Certain plums subject to this trouble have given much better crops on trees where these washes have been used for several years.

Effect on Growth—One very noticeable feature of trees sprayed with tar oil washes is that they produce a much more luxuriant foliage and retain their improved appearance for some time. Petherbridge and Weston (*J. Min. Agric.*, July, 1926) have shown that the leaves on sprayed trees are often 50 per cent. heavier than those on similarly unsprayed trees.

Growers using tar oil washes must be very careful to follow the instructions sent out by the makers. One of these is that the trees can only be sprayed when the buds are dormant; it is dangerous to spray when the buds begin to swell. In experiments conducted in 1925 (Petherbridge and Dillon Weston, *J. Min. Agric.*, July, 1926), Victoria plum trees sprayed on February 12 lost 90 per cent. of their blossom buds. In Hertfordshire in 1926, Victoria plums sprayed with 6 per cent. of one of these washes on January 30 lost 80 per cent. of their blossom buds, whereas the same variety was sprayed near Cambridge on January 29 without ill effect.

In normal seasons it is safe to spray plums up to the end of January, but in mild seasons the buds must be closely watched towards the end of that month. Apples can be safely sprayed some time after plums have reached the dangerous stage. Spraying should not begin until

FRUIT (*Continued*)—

most of the common pests have laid their eggs, *i.e.*, before the middle of November. The Winter Moth sometimes lays its eggs in December or later, so that trees sprayed during this month, or previously, should be banded if Winter Moth is at all prevalent.

The best time for spraying appears to be December and January for plums, and until the end of February or later for apples. The spraying should be done in dry weather, for rain immediately after spraying reduces its efficiency. It should not be done in frosty weather.

In some districts the water available for spraying is very hard and unsuitable to use alone with tar oil washes, as the emulsification breaks down and a brown oily substance separates out. This can be prevented by the previous addition to the hard water of from 2·5 to 5 per cent. of powdered size.

An unsatisfactory feature of tar oil sprays is that they scorch any green foliage growing underneath the sprayed trees. Where gooseberries or currants are the undercrop, the spraying should be done before the leaves of these bushes begin to show. With strawberries the old leaves are scorched, and where the plants are drenched, the crop may be seriously damaged. Flowers under sprayed trees may be severely damaged.

Quite recently, Tutin (*Ann. Rept. Long Ashton Res. Stat.*, 1927) has introduced a new tar oil wash known as the "Long Ashton winter wash," which differs from the old tar oil washes in being prepared by high boiling (280°-360° C.) neutral tar oil and a proprietary compound known as "Agral W.B.," which was found to be a very convenient emulsifier. Before use, the requisite amount of caustic soda is added. For very hard waters, such as obtain in the Wisbech and certain other districts, this wash can only be used when a large quantity of emulsifier is used, a considerable additional expense.

A number of proprietary one-solution modifications of the Long Ashton wash have now been placed upon the market. These are prepared from the same high-boiling oil, emulsified in a variety of ways, and several of them mix well with the very hardest waters.

The Long Ashton two-solution wash is more toxic to insect eggs than the old tar oil washes, and gives a better control of the various common fruit tree caterpillars, and, in some cases, has given a much better control of the Apple Capsid Bug, *Plesiocoris rugicollis*, and the common Capsid Bug, *Lygus pabulinus*, when applied at 10 per cent. strength (Staniland and Walton, *J. Min. Agric.*, Sept., 1929). A fairly high percentage of the eggs of these capsids were also killed when they occurred on black currants, but the control in this case is not so good as when the pests occur on apples.

The Long Ashton two-solution wash (and some of the one-solution modifications) is also more toxic to plant tissues than are the old tar oil washes, and may cause considerable damage to undercrops such as gooseberries and strawberries when used at 10 per cent. concentration.

Since the advent of the tar oil washes, there is no place in the spraying programme for the old winter washes such as lime and caustic soda.

FRUIT (*Continued*)—

Mineral Oil Emulsions—A number of proprietary mineral oil emulsions for use in the dormant season have recently been put on the market. Under certain conditions these emulsions give a good control of the Apple Capsid Bug (*P. rugicollis*), the Common Green Capsid Bug (*L. pabulinus*), and also of the Fruit Tree Red Spider (*Oligonychus ulmi*), but unfortunately they do not control Aphides.

Contact Insecticides—Nicotine is by far the most commonly used contact insecticide. With ordinary waters, soft soap at the rate of about 1 per cent. is added, to act as a spreader, as nicotine alone does not wet the plant sufficiently to reach the insects. With very hard waters, soft soap is too expensive, as the salts in the water combine with it and form a precipitate, thus necessitating a large percentage of soft soap to produce the spreading property.

Petherbridge and Kent have shown that with very hard waters (*J. Min. Agric.*, April, 1926) sodium caseinate gives results approximating those of soft soap.

"Agral 1," a proprietary spreader, has given results very similar to those given by soft soap.

Nicotine Dusts—Recently nicotine dust has found a place in the spraying routine in parts of America and in this country; it has given good results when used against Woolly Aphis. It has also been used against the Apple Capsid Bug (*P. rugicollis*), but in some experiments carried out at Wisbech in 1929 two dustings gave inferior results to one spraying with soft soap and nicotine. The best results are obtained in warm weather, as the efficiency appears to depend on the rate of volatilization of the nicotine. *Derris Extract*, when used with soft soap, acts both as a contact insecticide and also as a poison, but Fryer, Stanton, Tattersfield, and Roach (*Ann. App. Biol.*, vol. xii., 1925) have shown that it is not equal to nicotine as a contact wash.

Mineral oil emulsions are sometimes used as contact washes, but are not so effective as nicotine and soft soap except against "Red Spiders."

Pyrethrum, commonly met with in "insect powders," is again attracting attention as a contact spray. It has the advantage of being harmless to man and domestic animals.

Fryer, Tattersfield, and Gimingham (*Ann. App. Biol.*, xv., 1928, p. 423) have recently confirmed the results of other workers as to the high insecticidal value of pyrethrum, and shown that the plant (*Chysanthemum cinerariæfolium*) can be successfully grown and harvested without loss of toxicity in this country. (See Insecticides and Fungicides.)

The active principle of pyrethrum can be extracted by means of alcohols or light petroleum oils. Tutin (*Ann. Rep. Long Ashton Res. Stat.*, 1928) has prepared a spray fluid by dissolving the petroleum extract in a fatty oil and emulsifying with a proprietary emulsifier known as "Agral W.B.," and has shown that this wash will kill "Red Spider" and Raspberry Beetle (*Byturus tomentosus*).

FRUIT (*Continued*)—

Banding of Fruit Trees—The practice of banding fruit trees is very necessary in many orchards. There are two types of bands:

1. *The sticky band* which is used to control attacks of the various kinds of "winter moths" on apples, pears, plums and cherries. These bands, which prevent the wingless females from ascending the trees, should be put on the trees early in October, and kept in a sticky condition until April. The winter moths may be found from October to January, but the March moths usually emerge in February and March.

The sticky materials used are proprietary articles, and, except in the case of older trees with rough bark, they should be applied to a stout, grease-proof paper band which is tied firmly to the trunk about three to five feet from the ground.

The sticky material should form a complete band about three inches wide round the trunk of the tree.

2. *The hibernation band* is usually made of sacking or corrugated cardboard covered with grease-proof paper. These are used to provide hibernating quarters for the Apple Blossom Weevil (*Anthonomus pomorum*) and the Codlin Moth (*Cydia pomonella*). The bands should be *tied* firmly to the trunks by the beginning of June, and removed about the middle of November.

In some experiments at East Malling, Massee (*Ann. Rept. East Malling Research Stat.*, 1929) caught an average of three hundred and ninety Apple Blossom Weevils on thirty-seven corrugated cardboard bands.

In the autumn, small birds peck holes in the cardboard bands to get at the insects hibernating underneath them, and in so doing may pull the bands away from the trees. Thus, it is important that the bands should be fixed as firmly as possible.

The bands are also useful in trapping the hibernating caterpillars of the Codlin Moth, which have increased very much in commercial orchards during the last few years.

In private gardens the "hibernation band" is likely to be of much more value than the "sticky band," as in such the Codlin Moth is usually very prevalent, and the Winter Moths comparatively scarce.

The methods recommended for controlling the chief pests in commercial orchards are as follows:

Apple Pests—*Apple Aphides.* Spray during the dormant season with a tar oil wash (6 per cent. of most kinds is sufficient for this purpose, but 10 per cent. is often used in order to reduce the caterpillars at the same time).

Woolly Aphis (*Eriosoma lanigerum*) is not controlled by tar oil washes. Dusting with 3 per cent. nicotine dust gives a fair control, and is economical.

The Apple Capsid Bug (*Plesiocoris rugicollis*) (Plates XI and XII). In some districts 10 to 12 per cent. "Long Ashton tar oil" wash has given good results when applied shortly before the bud begins to swell, but in other districts this has proved disappointing.

The best winter wash control has been obtained with emulsions containing both mineral oils and high boiling neutral tar oils, but these

FRUIT (*Continued*)—

injure gooseberries and strawberries underneath, and sometimes injure some of the apple buds, especially in varieties like Bramley's Seedling. Certain proprietary mineral oil emulsions have given a good control when applied in winter at a strength of 10 per cent., but these washes do not control Rosy Apple Aphis.

In addition to winter spraying (if the bug is at all prevalent), trees should be thoroughly sprayed as soon as all the bugs have hatched, *i.e.*, about ten days before blossoming, with a solution made up of the following ingredients:

Soft soap	4 lbs.	in 40 gallons of water.
Nicotine, 95 to 98 per cent.	$3\frac{1}{2}$ ozs.	

For further details see Petherbridge and Kent (*J. Min. Agric.*, April, 1926).

Winter Moth Caterpillars (*Cheimatobia brumata*, etc.) are considerably reduced by spraying with 10 per cent. tar oil wash. If at all prevalent, the trees should also be banded at the end of September or beginning of October with a special banding material. As the eggs may not be laid before December, banding may also be necessary in cases where the trees are sprayed early, say in November. In addition to the above, lead arsenate is usually added to the fungicides, "lime-sulphur" or Bordeaux used to control apple scab (*Venturia inæqualis*).

Tortrix Caterpillars. Many of these are kept in check by spraying with 10 per cent. tar oil wash.

Apple Sucker (*Psylla mali*) is readily controlled by the tar oil washes used against aphis or caterpillar.

Apple Sawfly (*Hoplocampa testudinea*) (Plate XIII). Experiments in 1927 and 1928 (Petherbridge and Tunnington, *J. Min. Agric.*, February, 1929) show that this pest was markedly reduced by spraying, seven days after the petals had fallen, with:

Nicotine, 95 to 98 per cent.	4 ozs.
Soft soap	4 lbs.
Water	40 gallons

and that a second spraying seven days later gave a still further reduction.

The time of spraying relative to the time of blossoming is very important in the case of this pest.

Red Spider (*Oligonychus ulmi*). This pest can be kept in check by lime sulphur applied as soon as the petals fall, but the strength of the spray used varies with the variety. The usual apple scab sprayings with lime-sulphur after blossoming will keep this pest in check.

Good results have also been obtained by spraying in the dormant season with an emulsified mineral oil, and with a weaker emulsified oil in the spring (time of application as for lime-sulphur).

Plum Pests—*Leaf-curling Plum Aphis* (*Anuraphis padi*) is easily controlled by spraying with a 6 per cent. tar oil wash in December or January, but in cases where caterpillars are prevalent, the concentration of these washes is usually increased to $7\frac{1}{2}$ per cent.

PLATE XI

FIG I.—LEFT, EGG OF THE COMMON GREEN CAPSID BUG (*LYGUS PABULINUS*); AND, RIGHT, EGG OF THE APPLE CAPSID BUG (*PLESIOCORIS RUGICOLLIS*).

Both dissected from stems and magnified 60 times.

FIG. 2.—APPLE SHOOTS MALFORMED OWING TO THE SUCKING OF THE APPLE CAPSID BUG (*P. RUGICOLLIS*).

To face p. 480

PLATE XII

(a)

(b)

(c)

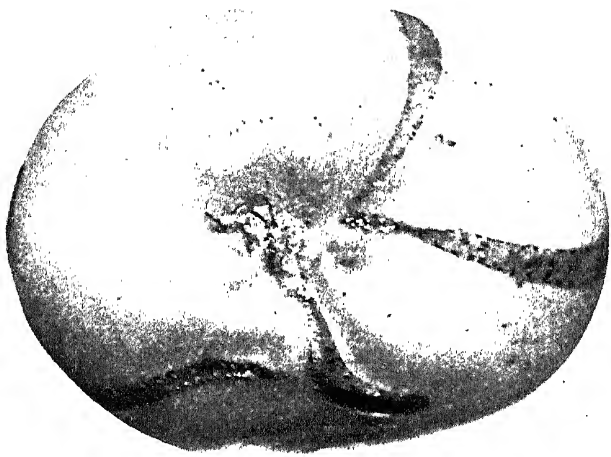
(d)

APPLES (VARIETY, LORD DERBY) SHOWING DAMAGE CAUSED BY APPLE CAPSID BUG (*PLESIOCORIS RUGICOLLIS*).

(a) Unmarked; *(b)* slightly marked; *(c)* and *(d)* badly marked.

To follow Plate XI.

PLATE XIII



RIBBON-LIKE SCARS CAUSED BY THE CATERPILLAR OF THE APPLE SAWFLY (*HOPLOCAMPA TESTUDINEA*).

To follow Plate XII.

FRUIT (*Continued*)—

Red Spider (*Oligonychus ulmi*) can be controlled by spraying with lime-sulphur (sp. gr. 1·3) 1 in 60, about a fortnight after the petals have fallen. Some mineral oil emulsions applied at the same time have given similar results.

Good results have also been obtained by spraying in the winter with an emulsified mineral oil.

Plum Sawfly (*Hoplocampa flava*). No satisfactory control is known, but promising results were obtained in 1929 by using soft soap and nicotine as for apple sawfly, when the plums were in full bloom, and again a week later.

Currants, Gooseberry, and Raspberry Pests—*Currant and Gooseberry Aphides* are readily controlled by spraying with a 6 per cent. tar oil wash in the dormant season.

The Common Green Capsid Bug (*Lygus pabulinus*) is difficult to control. It can be much reduced by spraying with certain mineral oil washes or with an emulsion containing mineral oils and high boiling neutral tar oils during the dormant season, and also by shaking the bushes and spraying the ground thoroughly after all the bugs have hatched (about the time that the petals of Bramley's seedling apple begin to fall) with:

Nicotine, 95 to 98 per cent.	3½ ozs.
Soft soap	4 lbs.
Water	40 gallons.

Black Currant Mite or Big Bud (*Eriophyes ribes*). This pest can be kept in check by spraying with lime-sulphur (sp. gr. 1·3) about the end of March when the leaves are about the size of a shilling.

The strength of lime-sulphur varies with the variety; those of the Victoria type, such as Edina, Goliath, and Victoria, which are more susceptible to spray injury, can be sprayed with 1 in 20 lime-sulphur. Other varieties can be sprayed with 1 in 12 lime-sulphur.

The Raspberry Beetle (*Byturus tomentosus*). This pest causes serious losses to raspberries and loganberries, and is also very common in some districts on wild blackberries. One method of control is, when the beetles appear, to beat the canes over boards covered with tree-grease or tar, but this method is not very satisfactory, especially with loganberries.

Lees and Peren (*Ann. Rept. Long Ashton*, 1921) have shown that three sprayings with lead arsenate reduced the infected fruit by about 75 per cent., but this method has not found favour with growers, probably owing to the poisonous nature of lead arsenate.

In some recent experiments on loganberries and raspberries, Walton (*Ann. Rept. Long Ashton*, 1929) has shown that spraying with an emulsion containing the active principles of pyrethrum dissolved in a fatty oil, when 25 per cent., 50 per cent., and 75 per cent. of the flowers respectively are open, brought about reductions in infestation of from 60 to 70 per cent.

F. R. P.

FRUIT (*Continued*)—

FRUIT PLANTS, MANURING OF—The problems involved in the manuring of fruit plants present many novel features, and it is necessary in considering them to take a very wide perspective of the numerous points which call for consideration.

At the outset, it is essential to realize that manuring is only one factor in the general problem of the nutrition of the fruit plant, and that the grower may often be able to eliminate what would normally be regarded as manurial problems by other means. (See Manuring, Principles of).

The factors involved in the nutrition of the fruit plant may be grouped as follows:

(*a*) Materials—including the class of fruit, varieties, rootstocks in the cases of the majority of tree fruits, and the age of the plant.

(*b*) Environmental factors—these may be divided into two sub-groups.

1. Natural conditions—including the climatic factors of rainfall, temperature, sunshine; soil factors, embracing chemical, physical and biological properties; parasitic organisms—pests, fungi, etc.

2. Artificial factors or factors introduced by the grower. These include soil treatment—cultural operations and manuring; control of pests, fungal and bacterial organisms, etc.; manual operations on the tree such as pruning, fruit thinning, bark ringing, etc.

The interrelationships of manuring and these other nutritional factors will be evident from the following examples: plums and black currants as classes require "high" nitrogen conditions; apples, gooseberries, and red currants are generally susceptible to failure under "low" potassium feeding; varieties and rootstocks exhibit a large range of resistance to unfavourable nutritional conditions; old plants show great need for nitrogen; plants in high rainfall areas behave like "high" nitrogen plants, whilst dry soil conditions tend to mitigate the effects of wet climatic conditions; low cultural conditions tend to produce "low" nitrogen conditions within the plants and may lessen the effects of potassium deficiency; pruning may produce marked growth responses similar to those effected by manuring.

Two further points which it is essential to emphasize at this stage are the various specific purposes for which manures may be applied, and the changing character of the manurial problem which the fruit plant presents during its life in the plantation.

In connexion with these points, it may be mentioned that in the young stages of a plantation of tree fruits, the grower is not greatly concerned with crop production at that time, for his immediate aim is to grow a sturdy and healthy tree that will be capable of carrying crops in future years, and to this end he may deem it desirable to manure fairly liberally. Later, when the trees have reached the bearing age, the system of manuring may be determined by the type of fruit required, whether highly coloured dessert specimens or large green fruits with special culinary qualities. At this stage also, the difficult problems relating to the balance between growth and fruitfulness arise, problems which present innumerable complications as

FRUIT (*Continued*)—
the result of the effects of the various environmental factors, and which rule out the possibility of adopting any stereotyped routine methods of manuring without reference to the special condition of the plants at any particular time.

It will be clear from the above statements that specific recipes for the manuring of fruit plants are likely to prove of little value. The only sound basis for the intelligent use of manures on fruit plants is a detailed knowledge of the effects of the various factors involved in the nutritional problems in each particular case. The grower must learn to diagnose the condition of his plants and to evaluate the relative effects of the individual factors which are operative. Considerable guidance in these matters is now available as the result of recent investigations, and in this connexion, the references appearing in the present text should be consulted.

Historical—Previous to 1920, the number of comprehensive manurial experiments on fruit crops carried out in this country was extremely small, the only investigations of note being those of Bedford and Pickering at Woburn (Duke of Bedford and S. U. Pickering, *Woburn Exptl. Farm Repts., 1st, 4th,* and *16th Reports,* "Science and Fruit Growing," 1919), and of Dyer and Shrivell at Hadlow, Kent (B. Dyer and F. W. E. Shrivell, "The Manuring of Market Garden Crops," 1913). Nor had the subject been considered to any extent in European countries, since the only scientific publications referring to nutritional problems are in connexion with various pathological conditions of fruit plants such as chlorosis and "die-backs."

The subject had, however, attracted much attention in the United States of America from about 1890, and during the period just prior to 1920 the results of many of these experiments, often carried out over long periods, were published.

The literature referring to this early work has been reviewed in some detail in a previous communication (T. Wallace, *J. Pomol. and Hort. Sci.,* vols. iv., v., 1925), but in order to emphasize the nature of the main results obtained, and the relatively small amount of knowledge gained from these early experiments, some reference is made below to the results at Woburn and Hadlow, and to the main features of the United States results as summarized by W. H. Alderman in 1919 in criticizing the methods used in the early investigations (*Proc. Amer. Soc. Hort. Sci.,* 1919).

Experiments in England—At Woburn, experiments were carried out over a period of twenty-two years on apples, bush fruits, and strawberries, on two widely differing soil types—a heavy clay soil at Ridgmont, and a light sandy soil, deficient in potash, at Milbrook.

At Ridgmont the results appeared of a most curious character. On apple trees, both dung at 30 tons and 10 tons per acre and "complete artificials" equivalent in plant food content to 30 tons and 10 tons of dung per acre per annum produced no significant effects either on the growth or fruiting of the trees, whereas large increases were obtained on the same soil from similar treatments, especially

FRUIT (*Continued*)—

with dung on bush fruits—particularly on gooseberries—whilst vegetable crops and young nursery stock also responded normally to fertilizers on this soil after the removal of the apple trees used in the experiment. The ploughing in of green crops produced bad effects on apple trees on this soil.

Pickering, in discussing these results, draws attention to the fact that the cropping of the apple trees was affected to a certain extent by the destructive action of spring frosts, but appears to have accepted them as being natural for a heavy and fairly fertile soil.*

In the experiments on apples at Milbrook, large increases in crops were obtained both from dung and "complete artificials," and further experiments indicated that the major problem was that of potash deficiency. The following Table, taken from the results, illustrates this point:

TABLE I.

RESULTS ON APPLES AT MILBROOK.

	No Manure.	*Complete Artificials.*	*Omit K_2O.*	*Omit P_2O_5.*	*Omit N.*
Relative yields ..	72	100	67	117	103

On this soil, large crop increases were also obtained by the use of dung, and smaller increases resulted from artificials on gooseberries, whilst similar results over shorter periods were obtained from these treatments on currants and raspberries.

With strawberries, no crop increases resulted from any manurial treatment, although dung appeared to prolong the lives of the plants.

The Hadlow experiments were designed to ascertain how crops obtained by manuring with light dressings of dung supplemented by artificial manures, or with artificial manures alone, compared with those obtained by manuring with heavy dressings of dung alone.

The experiments were carried out on apples, plums, gooseberries, currants, and strawberries under conditions of clean cultivation on a soil described as a clay loam overlying a deep bed of heavy clay, and which was said to be a very poor soil.

The results obtained with all crops excepting strawberries led to the following conclusions:

1. That a light dressing of dung supplemented with a complete dressing of artificials was as efficient for crop production as a heavy dressing of dung.

2. That "complete artificials" alone generally gave smaller yields than dung.

3. That the omission of potash from the "complete artificials" resulted in yields much below those from the plots receiving the "complete artificials," and that the plants on these "potash omitted" plots generally failed to make healthy growth.

* The writer has had an opportunity recently of examining the growth features of apple trees at Ridgmont, and is of opinion that many of the trees on the plots have failed to make healthy growth due to serious deficiency of potassium. Apparently the experimental methods used in the manurial experiments failed to establish this deficiency.

FRUIT (*Continued*)—

After ten years of experimenting on apples, these investigators wrote: "The outstanding feature of the experiment is the small crops produced on the plots manured with artificials from which potash manures have been omitted."

Thus, in 1911, which was a good season, the yields for apples were:

	Cwts. per Acre.
"Complete artificials" plot	103
"Complete artificials" less potash plot	45

In the experiments on strawberries no consistent results were obtained.

Experiments in U.S.A.—Alderman (*loc. cit.*), in reviewing the results obtained in manurial experiments in the United States up to 1919, makes the following statements:

"This seems to be a suitable occasion to pause and consider the work that has been accomplished to date. Within the past two years a number of well-conducted field experiments, extending over long terms of years, have matured, and the results have been made public. So much has been written on the subject that it is a bit difficult to summarize the case, since the evidence does not all point in the same direction. It is somewhat simpler if we confine ourselves to the points over which there is seemingly no contention.

"1. There are apparently a great many orchards growing upon a variety of soils that will not respond economically to the application of any form of commercial fertiliser, nor of manure. This fact is well established by the work in New York, New Hampshire, Maine, West Virginia, and other states.

"2. Orchards are much more likely to respond favourably if they are given sod mulch treatment than if kept under cultivation. A comparison of the work in the above-mentioned states with that in Massachusetts and Ohio furnishes interesting evidence upon this point, as does the work in Pennsylvania, where the three sod orchards displayed considerably greater gains than the three under cultivation.

"3. Orchards under starvation conditions usually give a ready response to fertilisation when other treatments (culture, pruning, spraying, etc.), remain unaltered. This is well demonstrated by some of the Ohio, Oregon, and West Virginia experiments.

"4. Nitrogen in a readily available form seems to be the only element of plant food that is uniformly a factor in the favourable responses when such are secured."

Two further points relating to these United States results, and not referred to by Alderman on this occasion, require mention.

These are that in several experiments on tree fruits, it was found that phosphates applied to cover crops to be ploughed in proved of indirect benefit to the trees by increasing the growth of the cover crop, whilst the use of potash manures usually yielded negative results (T. Wallace, *loc. cit.*).

FRUIT (*Continued*)—

Recent Investigations in England—Since 1920, important advances have been made in manurial problems in this country.

At Long Ashton (Wallace, T., *Agricultural Progress*, vol. vii., 1930; *Ann. Appl. Biol.*, vol. xvii., 1930), problems of fruit-tree nutrition have been intensively studied by laboratory and pot-culture methods and in field experiments, whilst at East Malling (R. G. Hatton and N. H. Grubb, *J. Pomol. and Hort. Sci.*, vol. iv., 1925; N. H. Grubb, *ibid.*, vol. vii., 1928; J. Amos, R. G. Hatton and T. N. Hoblyn, *Ann. Appl. Biol.*, vol. xvii., 1930) various aspects of manuring have been studied in field experiments.

In addition to the work at these stations, manurial experiments have been in progress on County Council plots, and at certain of these centres results of value have been obtained.*

In the Long Ashton investigations, special attention has been given to the effects of deficiencies of the major elements—N, K, P, Mg, Ca, S—on various fruit plants; to the diagnosis of nutritional problems in the field; to the correlation of manurial responses with chemical features of the plants; to the interrelationships of manuring to materials and environmental factors; and to problems of fruit yield and quality.

These investigations have served to establish certain facts of great value to the grower, viz.:

1. Potassium deficiency is the most important manurial problem in connexion with fruit plants in the fruit-growing areas of this country (T. Wallace, *J. Pomol. and Hort. Sci.*, vols. vi., vii., 1928).

2. Problems relating to the use of nitrogenous fertilizers are of great importance, especially in connexion with the production of dessert and culinary varieties of tree fruits and all grades of soft fruits.

3. Problems of phosphatic manuring appear to be of much less importance than those relating to the use of nitrogenous and potassic manures.

4. Soil acidity has not proved important, though calcareous soils present difficult problems in connexion with chlorosis associated with deficiency of iron (T. Wallace, *J. Pomol. and Hort. Sci.*, vol. v., 1926; vol. vii., 1928 and 1929).

5. Interrelationships between manurial practices and other factors have been established as under:

(*a*) Sod culture induces nitrogen deficiency and lessens the need for potash manuring (T. Wallace, *loc. cit.*).

(*b*) Various classes of fruits and certain varieties, etc., exhibit special nutrient requirements. These cases are of great importance in connexion with requirements for potassium (T. Wallace, *loc. cit.*).

(*c*) Potassium requirements are greatest on light, sandy soils; on shallow, close-textured, and poorly weathered soils; and on heavy soils in wet situations (T. Wallace, *loc. cit.*).

* Lancashire County Council Station, Hutton; Somerset County Council Station, Cannington; Worcestershire County Council Station, Perdiswell.

FRUIT (*Continued*)—

6. Manurial deficiencies may be recognized by growth features (T. Wallace, *loc. cit.*).

7. Fruit yield and quality may be greatly altered by manuring where responses from nitrogenous or potassic manures are obtained (T. Wallace, *Proc. Imp. Hort. Conf.*, London, 1930).

The East Malling experiments have corroborated the Long Ashton results relative to the importance of potash manuring for apple trees, and have also emphasized the necessity of considering materials—varieties and rootstocks—in manurial problems.

The importance of dung and nitrogen in manuring black currants has also been shown at this station (R. G. Hatton, *Ann. Rept. East Malling Res. Stat.*, 1922).

On the various County Council plots, the outstanding point which has been demonstrated is the importance of potash manures, especially for apples, gooseberries, and red currants. The oldest and most interesting of these plots are the Lancashire County Council plots at Hutton (A. G. Sowman, *Proc. Hort. Educ. Assn.*, 1925), where potassium deficiency is evidenced in most striking fashion on apples.

U.S.A.—In the United States during the past ten or twelve years, attention has continued to be focussed chiefly on the effects due to nitrogenous manuring, and it is curious, in view of the results obtained in England, that results from potash manures are practically never obtained. Perhaps the only case of a striking deficiency of potassium in fruit trees recorded in America is that reported by Hoagland and Martin in prune trees in California (D. R. Hoagland and J. C. Martin, *Proc. First Internat. Congress of Soil Sci.*, Washington, 1927).

These recent studies in America have been greatly influenced by the $\frac{\text{carbohydrate}}{\text{nitrogen}}$ theory of Kraus and Kraybill (E. J. Kraus and H. R. Kraybill, *Oregon Agric. Expt. Stn. Bull.*, 149, 1918), which attempts to provide a basis for explaining the states of "growth" and "fruitfulness" in plants. Using this hypothesis as a starting point, intensive studies have been made on the action of nitrogenous manures on fruit bud formation, fruit "set," biennial bearing, etc.

It cannot be said that these later experiments have advanced the practical problem much beyond the point of the older work, though knowledge relating to the effects of nitrogen on fruit yield and quality under various field conditions has been given a greater measure of precision.

A practical outcome of these investigations has been the adoption in certain fruit sections of the cultural system of growing tree fruits—mainly apples—known as the sod-mulch method, under which the trees are grown in sod and manured with nitrogenous fertilizers such as nitrate of soda or sulphate of ammonia, the grass being cut at intervals and allowed to rot *in situ* or in heaps placed under the area of the spread of the trees.

Manurial investigations on fruit plants still appear to be regarded as of small consequence in Europe, although from publications it

FRUIT (*Continued*)—

seems evident that potassium deficiency is of importance in the vine-growing areas in France (T. Wallace, *loc. cit.*, see refs.), and in the hardy fruit areas of Holland and Germany (T. A. C. Von Schoevers, *Die Ernährung der Pflanze.*, Bd. 25, Heft 13, 1929).

Deficiency Effects on Fruit Plants—In the investigations at Long Ashton, the effects of deficiencies of N, K, P, Ca, Mg, and S have been studied in considerable detail. The results of these investigations have been published elsewhere (T. Wallace, *loc. cit.*), but since it appears that manurial operations can only be carried out effectively when the condition of the tree can be diagnosed, the effects of deficiencies of nitrogen, potassium, and phosphorus are set out in detail below.

The features which have been found to be of diagnostic value are as follows:

(*a*) Times of opening of leaf and blossom buds;
(*b*) Blossom characters;
(*c*) Foliage characters throughout the season;
(*d*) Shoot growth;
(*e*) Defoliation phenomena—relating to time, method, and tints developed;
(*f*) Conditions of barks;
(*g*) Yields and characters of fruits;
(*h*) Root systems.

The effects described below have been produced in controlled pot experiments, using sand cultures, in which the various plants have received their supply of the necessary elements solely from chemical solutions, or in field investigations in which the respective deficiencies have been conclusively proved.

Nitrogen Deficiency—The omission of nitrogen from nutrient solutions produces deleterious effects more quickly than in the case of the omission of any other of the elements, and usually, by the end of the first season of treatment, trees receiving this treatment show growth amounts similar to others receiving "water only."

The times of opening of the blossom and leaf buds are delayed, blossom formation is drastically reduced owing to the death of lateral buds, and the flowers are extremely weak. The amount of foliage developed is very scanty, and, after a season or two of the treatment, the trees and bushes usually carry foliage only at the tips of the shoots. The plants thus develop a characteristic "bare wood" appearance. In the case of strawberry plants, the number of crowns produced is small.

The leaves are relatively small and yellowish-green in colour, and may develop reddish tints towards the end of the season. It is not unusual for small reddish-brown spots to be developed on the leaves.

Shoot growth is very drastically reduced, even within the course of one season, and trees, after two or three seasons of the treatment, are usually unable to make appreciable shoot growth.

PLATE XIV

FIG. I.—APPLE TREE (VARIETY, LANE'S PRINCE ALBERT), THREE SEASONS AFTER PLANTING, UNDER CONDITIONS OF POTASSIUM STARVATION.

Note the failure to make appreciable growth and the dying back of the tips of the dwarfed shoots.

FIG. 2.—APPLE TREE (VARIETY, LANE'S PRINCE ALBERT), THREE SEASONS AFTER PLANTING, UNDER CONDITIONS OF ADEQUATE POTASSIUM SUPPLIES.

FRUIT (*Continued*)—

Defoliation is hastened and the tints at defoliation time are reddish-yellow.

The barks of trees are pale brown in colour.

Fruiting is reduced to a negligible amount in a very short period owing to the suppression of the lateral buds. The fruits are small, and some idea of the general effect of the treatment on quality in the various fruits may be obtained from consideration of the case of the apple. In varieties which develop red-coloured skins, such as Worcester Pearmain, the colour is greatly intensified, and the whole fruit may either assume a vivid scarlet colour or there may be a pale, almost white ground colour with a brilliant red flush. Reducing the nitrogen content of fruits is the only known manurial method of *consistently* producing high "colour" in our coloured varieties of hardy fruits. In green varieties, such as Lord Grosvenor, the fruits lose their green pigment, and in extreme cases are quite chlorotic. The flesh of the fruit is hard and lacks juice, percentage acidity is usually relatively high and the percentages of nitrogen and sugars are low, though the ratio $\frac{\text{sugars}}{\text{nitrogen}}$ is high. Flavour only develops slowly after picking, and the fruits are long keepers both in Ordinary and Low Temperature stores. (See Refrigeration.)

The root systems are small and in proportion to the dwarfed shoot portions, and it is notable that they consist almost wholly of fine fibrous material.

Potassium Deficiency—In sand cultures, the effects of potassium deficiency are less drastic than those resulting from the omission of nitrogen, though, in the field, starvation from the former element is a much more serious problem than from the latter.

In sand culture experiments, deficiency of potassium has frequently advanced the opening of blossom and leaf buds, and the blossoms formed have been strong and normal in every way. The number of blossom buds is not drastically decreased as in the case of nitrogen deficiency, and indeed may show some increase due to the fact that, under this treatment, shoots frequently die back and fruit buds rather than shoot buds are developed. This condition is often extremely marked in cases in the field where almost all terminal buds may be fruit buds. (Plates XIV and XV).

During the early part of each season the foliage characters are usually quite normal in appearance, but later, usually from the beginning of June, the special symptoms of the shortage of potassium become evident. The green colour at this stage is often bluish-green, and there may be slight chlorosis near the margins and between the veins. In some varieties of plum, the chlorotic symptoms are strongly marked. In gooseberries, and to a less extent in strawberries, the leaves at this stage may show purple tints, but later, especially in the gooseberry, these tints usually disappear entirely. There is often a tendency for the edges of the leaves to curl backwards towards the under surfaces, but in the case of certain plums, *e.g.*, Purple Pershore, the curling effect is in the reverse direction. The leaf margins finally

FRUIT (*Continued*)—

become brown or grey, following the death of the cells in these areas, and the leaves at this stage exhibit the condition known as "leaf scorch." This stage is usually well marked by the end of July.

In the case of plants like the raspberry, the browning generally extends between the veins from the marginal areas practically to the midrib. The development of scorch is most marked in hot, dry summers.

In advanced stages of potassium deficiency, leaf size is considerably reduced.

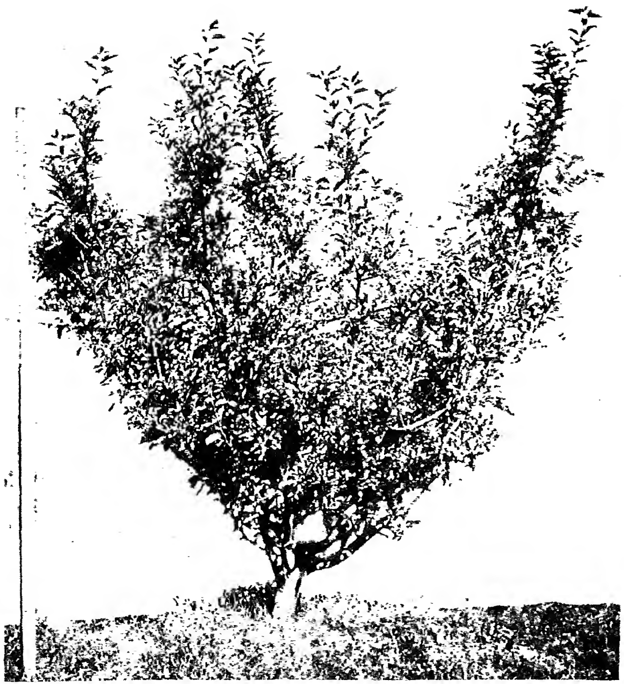
In pot experiments, shoot growth is usually somewhat reduced, but in certain cases with apples, during the first two or three seasons, shoot growth in the potassium deficient series has been greater than in the complete nutrient series. The amount of shoot growth in the case of potassium deficiency in this type of experiment appears to be influenced greatly by certain points of technique. Thus if adequate measures are taken to keep the sand medium invariably cool and moist, large shoot growth may result, whereas if the sand is not efficiently protected from temperature changes, shoot growth is greatly curtailed. In cases of potassium deficiency, shoots and even whole branches frequently die back, and in the field the shoots usually die back to fruit buds, and in the later stages practically no terminal shoot growth is made, the terminal buds being blossom buds.

Defoliation from potassium deficiency in the field occurs prematurely, following the development of marginal leaf scorch, and this frequently happens in pot experiments. Under the conditions which lead to good shoot growth in cases of potassium deficiency in pot experiments, defoliation may take place *later* than in the case of "complete nutrient" trees. When scorched trees defoliate early in the season, a second crop of foliage is frequently developed. During defoliation the colour of the leaves usually turns direct from green to brown or yellow, and highly coloured tints are generally absent. The method of defoliation is remarkable in that, whilst in all other cases examined it proceeds in the direction from the bases of the shoots towards the tips, the tip rosettes being usually the last foliage retained, in the case of potassium deficiency defoliation generally, but not invariably, proceeds from the tips of the shoots towards the bases, so that the tree retains the older leaves longest.

The colour of the barks may be slightly lighter brown than usual in severe cases.

Although potassium-deficient trees tend to develop fruit buds rather than shoot buds, the yields of fruit are greatly reduced. The blossoms set fruits quite freely, but most of the fruits drop during the season, and those which remain are small. The characters of these fruits are worthy of detailed note. In the case of the apple they may be of dull, unattractive appearance, being a duller green or less highly coloured than comparable high potassium fruits, and on keeping in store this appearance does not materially alter, the fruits always appearing less mature than well-developed fruits. On the other hand, they may be slightly more highly coloured at the time of picking than

PLATE XV



FI(H APPLE TREE (VARIETY, WORCESTER PEARMAI
AG RS, GROWN UNDER CONDITIONS OF ADEQU.
POTASSIUM MANURING.

FIG. 2.—BUSH APPLE TREE (VARIETY, WORCESTER PEARMAIN), AGE 10 YEARS, GROWN UNDER CONDITIONS OF POTASSIUM STARVATION.

Note the dying back of the branches.

To face p. 49c

FRUIT (*Continued*)—

high potassium fruits in the case of varieties such as Bramley's Seedling. In store they tend to shrivel, and in certain cases examined they exhibit a most remarkable storage feature in that, in the Ordinary Temperature store, they break down considerably *later* than high potassium fruits, but in the Low Temperature store they develop "breakdown" *prematurely*. (See Refrigeration.)

The fruits are usually of poor flavour, being sub-acid and often "woody," but they may be quite sweet and palatable. Chemically they generally show a normal percentage of nitrogen, relatively low acidity, total sugars may be high or low, but usually cane sugar is definitely low.

Root systems in the field are usually poorly developed, and badly scorched trees frequently feel quite loose when shaken. In pots, the roots may be quite normal in development, but cases have been observed where the potassium-deficient trees have failed entirely to form root systems.

Two important points which emerge from the data, both in pot and field experiments, are that potassium deficiency tends to promote physiological drought within fruit trees when the environmental conditions are conducive to drying out, and that the deficiency must usually be considered in relation to nitrogen supply (T. Wallace, *loc. cit.*; C. E. T. Mann, *Ann. Rept. Univ. of Bristol Agric. and Hort. Res. Stn.*, 1924).

Phosphorus Deficiency—The effects of phosphorus starvation of trees in sand cultures after two or three seasons are as severe as or more severe than those resulting from nitrogen deficiency, and the features exhibited in the two cases have many points in common.

The times of opening of blossom and leaf buds are appreciably delayed, and in extreme cases are delayed *beyond* the times when these occur in comparable trees receiving "water only." Blossom formation is greatly restricted owing to the death of lateral buds, and the blossoms formed are very weak. (Plate XVI, Figs. 1 and 2.)

The foliage exhibits very distinctive characters. The amount is very small, and eventually the only leaves developed are the terminal rosettes. Leaf size is much reduced.

It will be noted that all the features described above are similar to those due to nitrogen deficiency.

In the early spring, the leaves are fairly normal in colour, though of rather dull appearance, but they soon become increasingly so, and eventually exhibit characteristic purple and bronzed tints over their entire surfaces, the tinting often being accompanied by the presence of brownish spots, which are particularly in evidence in the case of the black currant. After bronzing, areas of the leaves may become dried out.

Trees undergoing phosphorus-deficient treatment frequently make excellent growth during the first season of the treatment, and show little effect from the deficiency—apparently because of the utilization of reserves—but, from the second season, shoot growth is generally

FRUIT (*Continued*)—

as severely restricted as from nitrogen starvation, and this condition continues from this point.

Defoliation is greatly advanced; it may occur in early June and *previous* to defoliation taking place in trees receiving "water only" treatment. After defoliation the trees do not show further signs of growth during the season.

The barks of the trees are slightly paler in colour as the result of the deficiency.

The yield of fruit is greatly affected, and is similar to that from nitrogen-deficiency treatment, as in both cases the reduced yields are due to suppression of the lateral buds. Unlike nitrogen-deficient fruits, phosphorus-starved fruits have no desirable commercial qualities, but are wholly undesirable objects. The colour is dull, with a suggestion of the bronzing which develops so markedly on the leaves. Very few opportunities have occurred for examining the chemical and storage qualities of the fruits owing to lack of crops, but the indications so far are that the fruits are poor keepers and lack character.

The root systems are small and in proportion to the small shoot growth, but the character of the root differs markedly from that in the case of nitrogen deficiency, consisting almost wholly of coarse roots and being practically devoid of fine fibrous rootlets. The roots are a characteristic brown colour.

Field Problems relating to Manuring—It was shown at the outset how closely manurial problems are interrelated to other factors which determine the nutritional condition of fruit plants, and examples were cited which illustrated the complexities of the field problems.

Of the many points which may be discussed in connection with manurial problems, there are certain which call for special mention because of their practical importance and academic interest, and these only are considered in this section.

They are as follows:

(*a*) The use of dung and the effects of nitrogenous, potassic, and phosphatic manures in the field.
(*b*) The use of lime.
(*c*) Types of fertilizers to use.
(*d*) Rates of application of manures.
(*e*) Time of application of manures.

(*a*) *The Use of Dung and the Effects of Nitrogenous, Potassic, and Phosphatic Manures in the Field*—In practically every experiment which has been carried out on bush fruits in which dung has been compared with "artificials," the conclusion has been reached that dung is superior in action on both growth and cropping to the "complete fertiliser" containing nitrogen, phosphorus, and potassium. Results of this type were obtained by Bedford and Pickering, Dyer and Shrivell and Hatton, and have also been obtained by the writer at Long Ashton. It has also been generally found that dung increases the longevity of the plants in such cases.

In the case of tree fruits, dung is usually of great benefit to stone

PLATE XV

FIG. 1.—BUSH APPLE TREE (VARIETY, ALLINGTON PIPPIN), GROWING IN SAND AND FED WITH A COMPLETE NUTRIENT SOLUTION.

Note the stage of blossoming.

FIG. 2.—BUSH APPLE TREE (VARIETY, ALLINGTON PIPPIN), GROWING IN SAND AND FED WITH A NUTRIENT SOLUTION FROM WHICH PHOSPHORUS IS OMITTED.

To face p. 492

FRUIT (*Continued*)—

fruits such as plums, but for fruits such as the apple, where firmness and keeping quality are important, its use in considerable quantities is usually not advisable.

Dung has been found to be an efficient source of potash in several severe cases of leaf scorch. (T. Wallace, *loc. cit.*)

Nitrogenous fertilizers have proved of great benefit to all classes of fruits in many situations. They usually produce increased growth and fruit yields on bush fruits, stone fruits, and pears, but less frequently on apples when these are grown under arable conditions. Under systems of "low cultivation" and "grass," nitrogenous fertilizers will usually produce marked results on growth and cropping of tree fruits, but it will often be found that similar or greater increases may be obtained more cheaply by adopting systems of higher cultivation. In several experiments of the writer,* it has been found that the response to high cultivation has been larger than that obtained from the application of nitrate of soda at 5 cwts. per acre applied in the spring to the "control" grass plot. A result of this type is shown in the composition of fruits from an experiment on apples:

TABLE II.

SHOWING THE EFFECT OF CULTIVATION AND OF NITRATE OF SODA AT 5 CWTS. PER ACRE ON THE NITROGEN CONTENT OF APPLES.

Treatment.	*Nitrogen as Per Cent. Fresh Weight.*	
	Variety—Newton Wonder.	*Variety—Lord Grosvenor.*
	Per Cent.	Per Cent.
Grass only	0·0299	0·0255
Grass+ $NaNO_3$ at 5 cwts. per acre ..	0·0316	0·0374
Cultivation only	0·0441	0·0485

Where large increases result from nitrogenous manuring, the quality of the fruit is usually appreciably affected. In fruits such as the apple, colour is affected adversely, the fruits are softer and more liable to bruise and possess relatively poor keeping qualities, being also more suitable for culinary than dessert purposes. Thus, it is often inadvisable to force production of fruits such as the apple with nitrogenous manures, except under low cultural conditions.

In cases of potassium deficiency, it is always advisable to withhold all forms of nitrogenous manures, for not only will increases not follow their use, but positive damage is likely to ensue. Since potassium deficiency is of such common occurrence in this country, it is therefore necessary to use nitrogenous fertilizers on fruits with caution, and to ensure that potassium supplies are adequate.

* Data unpublished.

FRUIT (*Continued*)—

The various problems relating to the use of potash manures on fruit trees have been described previously in great detail by the writer (*loc. cit.*) and others (*loc. cit.*), and only a few points require mention here.

Potassium deficiency is of very frequent occurrence in all the fruit-growing areas in this country, the condition of the affected plants being popularly known as "leaf scorch," and is by far the most serious nutritional trouble with which fruit growers have to contend.

Investigations have shown that serious deficiency of potassium may occur in fruit plants on areas on which the ordinary agricultural crops would not normally be expected to respond to potash manuring, and observation suggests that with many fruit plants such as apples, gooseberries, and red currants, it is unwise to proceed to establish plantations even on clay soils without ensuring a supply of potash by regular dressings of fertilizers. A point of great importance in connection with potash deficiency in fruit plants is the great difficulty often experienced in overcoming the trouble. It is not uncommon to find that large dressings of potash manures—say at the rate of 3 or 4 cwts. K_2SO_4 per acre per annum—are necessary over a period of three, four, or five years before substantial response is observed. This difficulty no doubt accounts for the failure to observe good results from potash manuring in some of the older experiments.

Although the effects of phosphorus deficiency on fruit plants have been shown to be extremely severe in sand cultures, no case of the deficiency has been proved in the field, and this in spite of the fact that special efforts have been made to discover cases in areas where agricultural plants fail badly from lack of phosphorus. It thus appears that fruit plants in this country are good phosphorus feeders.

Despite these results, it is felt that at the present stage it would be unsafe to assume that the application of phosphates to fruit crops is unnecessary.

(*b*) *The Use of Lime*—Lime has been freely applied to all classes of fruit crops in the past, and there is a common belief among growers that lime is essential to the proper development of stone fruits.

Critical experiments relative to the part played by lime in the nutrition of fruit plants are lacking, and at present it can only be stated that even on acid soils no beneficial effects from liming have ever been proved. So far, in the writer's experiments, liming has given negative results, and there seems no doubt that our fruit plants will at least tolerate fairly strongly acid conditions. On the other hand, serious cases of chlorosis occur in all fruit areas where the soils are definitely calcareous.

(*c*) *Types of Fertilizers to Use*—In English fruit areas, the so-called "organic" manures such as shoddy, hoof and horn, meat meal, etc., have been very popular, and it has been commonly held that "inorganics" such as nitrate of soda, sulphate of ammonia, superphosphate, etc., are unsuitable for fruit manuring.

In this connexion it must be remembered that, in many fruit

FRUIT (*Continued*)—

areas, market gardening is combined with fruit growing, and that dung is often unprocurable. There does not appear to be any critical evidence to justify the preference for the organic materials, though it might be expected that bulky materials such as shoddy would prove superior to inorganic nitrogenous fertilizers in the case of bush fruits, where soil moisture is of such importance during the fruiting period.

In the case of tree fruits, the problem has received most attention in the United States and, as the result of experiments, the quick-acting inorganic manures are favoured. Experiments on the point are in progress at Long Ashton, but so far no conclusions have been reached.

(*d*) *Rates of Application*—It is quite impracticable to lay down rates of manurial dressings which will be of general use. These depend entirely on the circumstances of the particular case. The grower must be guided by the appearance of his plants, his previous experiences of responses, the probability of cropping, or the amount of crop actually on the plants. Plants such as the plum and the black currant are gross feeders, but others, such as the apple, the gooseberry, and the strawberry, must be stimulated with care or unfavourable results such as excessive growth, liability to disease, or unfavourable quality of fruit may occur.

(*e*) *Time of Application of Manures*—This is another subject of a controversial nature on which critical data are lacking.

It is often stated that spring manuring produces growth, and that late summer or autumn manuring results in fruit-bud production. Hodsell advocated the application of a bud-forming manure in late summer for apples, but produced no data to substantiate his view (*J. Pomol. and Hort. Sci.*, vol. i., 1920).

While it is true that fruit plants normally lay down their fruit buds in the summer or early autumn for the production of fruit in the following year, it does not follow that the application of manures at that time will contribute to the process of fruit-bud formation (E. Ball, *J. Pomol. and Hort. Sci.*, vol. vi., 1927; T. Swarbrick, *ibid.*, vol. viii., 1930).

The important factor in fruit-bud formation appears to be the storage of carbohydrate materials, and it is difficult to see how the application of manures at the critical period will assist in this process.

Nitrogen is the only element in the manures which is likely to enter the plant at all quickly, even under favourable conditions, and this element may possibly prevent the accumulation of carbohydrate materials. In the case of potash, it is known that there is usually considerable delay before the material is found in the plant in cases of deficiency, whilst nothing is known of the rate of action of phosphorus.

In plants such as black currant, which fruit on young wood, it seems reasonable to expect greater effects from treatments which produce the greatest wood growth, and this would be expected from early spring dressings, since the bulk of the wood growth is made before midsummer.

FRUIT (*Continued*)—

In America, it is claimed that the application of quick-acting nitrogenous fertilizers previous to the blossoming period increases the "set" of fruit.

Conclusion—The foregoing survey will serve to illustrate the various aspects of the problems in connexion with the manuring of fruit plants and the progress which has been made towards the solution of the major points, and to focus attention on the large field which still remains to be explored.

It will be noted that until recently the subject had received scant attention in this country, a condition which was probably due to the character of the results reported in the earlier work and to the difficulties encountered in carrying out comprehensive experiments.

Manurial investigations on fruit plants necessitate long periods of experiment, relatively large areas of land, and the use of standardized materials, and call for exacting details of technique and elaborate records of tree "performance," thus being both expensive and laborious to carry out.

Such considerations, in the past, have doubtless discouraged critical investigations on the manuring of fruit plants, but the results of recent work have proved of such great value to the fruit-growing industry and have contributed so much of importance to the subject of plant nutrition that support for experiments in this branch of horticultural science should be assured in the future.

General References.—W. H. Chandler, "Fruit Growing," Houghton Mifflin Company, 1925; V. R. Gardner, F. C. Bradford, and H. D. Hooker, "Fundamentals of Fruit Production," McGraw-Hill Book Company, New York, 1922.

T. W.

FURROW—Furrow is usually taken to mean the hollowed-out piece of ground between two ridges, and marks the final operation in ploughing. (See Mould Furrow.) The ground which a plough turns over is called the furrow slice, but the track or small trench which is left by the plough is known as a furrow. (See Ploughing.)

FUSARIUM—See Diseases of Cereals, under Wheat.

GAITING—Gaiting is a method of setting up sheaves singly when the crop has been cut in a wet condition. The band of the sheaf is tied loosely round the straw just under the heads of corn, and the lower part of the sheaf is made to stand by spreading out the ends of the straw. Grass cut for seed is not infrequently "gaited" at the present time in Scotland and Northern Ireland.

GAME, COMPENSATION FOR DAMAGE BY—See Improvements and other Rights, Compensation for.

GEESE—See Poultry.

GERBER, METHOD OF FAT DETERMINATION—See Milk.

GINGER—The peeled or unpeeled rhizome of *Zingiber officinale,* a plant belonging to the order Zingiberaceæ, and bearing a spike of yellow

GINGER (*Continued*)—

and purple flowers more or less spotted, with a single blue anther and petaloid staminodium. The peeled rhizome is white ginger, the unpeeled, brown ginger. On distillation it yields a yellow aromatic oil containing a mixture of terpenes, etc., of which the chief are phellandrene, zingiberol, and zingerone. It is used in the perfumery, confectionery, and liquor trades, and as a carminative stomachic in medicine.

GLASSHOUSE CROPS—The cultivation of crops under glass in the British Isles occupies some 3,000 acres of glasshouses, representing £12,000,000 invested capital. It employs nearly 20,000 men and has an annual wage bill exceeding £1,500,000.

The chief districts are the Lea Valley, west Sussex, east Sussex, north-west Kent, Thames Valley, Norfolk, Lanarkshire, and Guernsey areas. Of these the largest is the Lea Valley, which comprises some 1,400 acres. The chief glasshouse crop is the tomato, but cucumbers, chrysanthemums, carnations, roses, grapes, melons, and mushrooms are also grown extensively. Other crops include peaches, nectarines, strawberries, beans, lettuce, arums, lilies, and such decorative plants as heaths, ferns, and geraniums.

Glasshouse management is a striking example of applied science, many of the larger nurseries being conducted almost on factory lines. Many improvements have resulted from the need for high-grade produce, easier working, and a higher standard of packing, made necessary by increased competition.

Nursery Planning—Modern nurseries are designed so that the central heating plant, coal stores, packing sheds, etc., are situated at the centre of the nursery. Glasshouses are built in blocks, varying from ¼ acre to 2 acres in extent, round this central point, and a good straight road connects it with the public thoroughfare. Light railways radiating from the centre serve to expedite the transport of materials to more distant parts of the nursery. The water supply, comprising deep artesian well, pumping plant, and reservoir, is placed far away from the houses, to prevent any chance contamination gaining entrance to it.

When designing the " lay out " of a new nursery it is advisable to make allowance for future extension, and the first erections should form the nucleus of the final scheme. Lack of forethought at first has frequently caused much inconvenience.

Central Heating—During the past five years central heating has come into favour with the owners of relatively large nurseries. Steam, generated in a large Lancashire or Cochran boiler, is conveyed to the glasshouses in buried pipes, and injected into the water pipes by means of specially devised distributors. By this means the water in the pipes is heated and circulated—a method that has several advantages. The numerous small tubular hot-water boilers, previously used, are replaced by one central boiler; heat control is more flexible and accurate, and some economy in fuel and labour is claimed. The method is new, but worth trying in large nurseries. On those less than 4 acres in

GLASSHOUSE CROPS (*Continued*)—

extent it is probably best to retain the old tubular boilers, for the capital outlay and cost of skilled stoking is excessive for small nurseries.

Water Supply—Recent work has shown that too much care cannot be expended on the water supply (W. F. Bewley, and W. Buddin, "On the Fungus Flora of Glasshouse Water Supplies in Relation to Plant Disease," *Ann. App. Biol.*, vol. viii., No. 1, pp. 10-19). A deep artesian well is a good investment, for clean water is assured. Shallow surface wells, ponds, and streams are often contaminated with disease organisms, which cause serious damage to glasshouse crops. Shallow wells situated near the glasshouses often become contaminated by drainage water, and wells should be placed far away from the houses.

House Construction—Steel structures are not suitable for the British climate, for the temperature variations cause excessive expansion and contraction, and consequently it is almost impossible to keep such structures rain-proof. Recent improvements are related to the question of ventilation and air space. Modern houses tend to be higher; for example, the aeroplane type of tomato house, with gutters placed 7 ft. above the ground, in comparison with the old type of vinery with gutters 4 ft. 6 ins. high. Ventilators are also being placed in the ends of the houses, on either side of the door and above it. Box ventilators, some 2 ft. from the ground, are rarely used.

Glass—The old Belgian blown 21-oz. glass, 18 by 20 ins., is being displaced by British glass, which has improved considerably of late years.

Several types of ultraviolet-ray transmitting glass, such as Vitaglass, Sanalux, and Vioray, are attracting the attention of nurserymen. Increased cucumber crops have been obtained only during the first year; no increase being observed during the second year. Such materials will receive more attention from investigators in the future, but their present price seems prohibitive for commercial purposes.

Electric Light—Recent work suggests that electric light may be used to advantage during the winter months to increase the hours of light to which young plants are exposed. It was found at Cheshunt that the dry matter of tomato plants exposed to a light intensity of 50-ft. candle power from 7 to 9 a.m., and from 4 to 7 p.m. daily, for a month, was three times greater than that of similar plants grown under normal conditions.

House Hygiene—Insect pests, and the organisms which cause plant diseases, find harbourage in the superstructure and walls of glasshouses as well as in the soil. Thus, it is necessary to clean down thoroughly when the houses are empty. This is best achieved by spraying with a reliable insecticide and fungicide, using a high-power machine and a nozzle designed to throw a strong, sharp jet. The spray must be driven with considerable force towards every part of the structure, and into every nook and cranny. The best fungicide is probably formaldehyde, but it is not so potent against insects as cresylic acid, and as the latter is a reasonably good fungicide it is usually employed for the dual purpose of destroying insects and fungi. The pale straw-coloured material, 97 to 99 per cent. purity, may be used alone with water at a strength of 1 in 40, or emulsified with soft

GLASSHOUSE CROPS (*Continued*)—

soap. The emulsion is prepared by adding 1 gallon of cresylic acid to 8 lbs. of a good potash soft soap and heating over a fire until the soap is dissolved. One part of the emulsion in 39 parts of water makes a useful spray; in the case of very dirty houses it should be strengthened to 1 in 9. Better penetration is obtained on unpainted wood or on old paint than on newly painted wood with a glossy surface.

During the process of spraying, and for the following few days, the houses should be heated to between 60° and 70° F. (15° to 21° C.), because the best "kill" is obtained at relatively high temperatures. If formaldehyde is used, 1 part of the 40 per cent. commercial material should be diluted with 49 parts of water.

Soil Sterilization—The cultivation of the same crop for a number of years leads to a soil condition commonly known as "soil sickness," due to the accumulation of root diseases, pests, and the chemical products of manuring and root decay. On heavy soils this condition may arise as early as the fifth year. It is counteracted by soil sterilization, accomplished either by heat or chemical sterilizers.

Heating the top 2 ft. of soil to a temperature of 210° to 212° F. for from twenty to forty minutes constitutes the most successful method of sterilizing the soil *in situ* in the houses. Soil for propagation, or for frames, may be steamed or baked.

Chemical sterilizers are numerous, the most successful being formaldehyde. One gallon of 40 per cent. commercial formaldehyde is diluted with 49 gallons of water, and the 50 gallons of diluted material is watered over 18 square yds. of soil surface, previously cleaned up and levelled. The soil should be forked over immediately after treatment to mix the liquid thoroughly with the top 12 ins. The vapours of formaldehyde are highly poisonous to plants, and the treatment should be carried out immediately the crop is finished, preferably before the end of November. Living plants should not be taken into the houses until six weeks have elapsed. Chemical sterilization is most effective on light soils, heavy soils being difficult to saturate with sterilizing fluids.

Practical sterilization of the soil by heat is described:

(*a*) W. F. Bewley, "Practical Soil Sterilization by Heat for Glasshouse Crops," *J. Min. Agric.*, vol. xxxiii., No. 4, July, 1926, pp. 297-301.

(*b*) W. F. Bewley, "The Practical Sterilisation by Heat of Small Quantities of Soil," *J. Min. Agric.*, vol. xxxvi., No. 7, October, 1929, pp. 623-634.

(*c*) *Min. Agric. and Fish.*, Bull. No. 22,

Steam is generated by a suitable boiler, conveyed into the houses by "lagged" pipes, and passed into the soil by means of either trays, spikes, or buried grids. The buried grid system is the most efficient, for by this method thorough and deep sterilization is possible. In the case of tomatoes it costs £130 to £150 per acre, and the effect lasts for three to four years. By its means crops of 35 tons per acre have been increased to 42, 45, and even 50 tons per acre.

Steam sterilization cannot be too highly recommended to nurseries where poor crops are grown.

GLASSHOUSE CROPS (*Continued*)—

THE TOMATO—The tomato is the staple glasshouse crop of this country, and in the Lea Valley area alone some 36,000 tons are produced annually. The red varieties are generally cultivated, there being only a limited market for yellow types.

The most popular varieties are **Ailsa Craig, Tuckswood, Potentate, Riverside Favourite, Blaby, Blako,** and **Comet. E.S. 1,** raised by the Cheshunt Experimental Station, is a high-class tomato, but the fruit is small in many nurseries. **Kondine Red** and **Best-of-All** are widely grown in Guernsey.

Commercial varieties, with few exceptions, are not pure line strains, and although they produce high-class fruit, considerable variation in cropping power exists between individuals. An attempt is being made at Cheshunt to analyse existing stocks and produce certain definite varieties which will breed true. The first advance was the raising of **E.S. 1** from a cross between **Ailsa Craig** and **Blaby.** It was found that segregation occurs within the plant, and that the progeny from one fruit on a plant may not be similar to that from another (W. F. Bewley and A. A. Richards, "Some Observations on the Progeny of a Single Tomato Plant," *11th Ann. Rept., Exp. and Res. Stat. Cheshunt*, pp. 136-141, 1925). The variety **E.S. 1,** which is pure for most characters, was obtained from two fruits on a plant, the remaining fruits giving rise to impure mixtures. **E.S. 1** possesses fruit of uniformly good shape and colour, with strong, healthy foliage, and is being used as the basis for further breeding. **E.S. 3,** obtained by crossing **E.S. 1** and **Comet,** produces large, well-shaped fruit, and on further selection should constitute an excellent commercial variety. Certain varieties are resistant to Leaf Mould (*Cladosporium fulvum*)—namely, **Up-to-Date, Stirling Castle, Maincrop,** and **Satisfaction**—but the fruit is undesirable. They are being used in breeding with the object of combining resistance to this disease with good fruiting qualities.

Clean seed is important, for mosaic disease is transmitted through the seed. Infected stocks have been cleaned at Cheshunt by removing from the seed house all infected plants as soon as they appear. In this way the spread of infection was prevented, and seed was taken from healthy plants. (See Virus Diseases.)

Selected seeds are sown in seed boxes either thickly or 1 in. apart. When sown thickly they are "pricked off" into boxes, 1 in. apart. Under ideal conditions of light, etc., the best seedlings are obtained by sowing thinly, but in poor light it is an advantage to sow thickly and then "prick off."

Germination should be rapid. This is achieved by maintaining a temperature of 70° F. (21° C.) until the cotyledons show above the soil. Once the seedlings are through, the temperature should be lowered to between 60° and 65° F. (15° and 18° C.), otherwise the growth becomes too soft and weak seedlings result.

Under very dull conditions the temperature may be reduced to 55° F. (12° C.) with advantage.

Cultivation—Good crops of tomatoes may be grown on all types of soil during the first few years of cultivation. On all types the crop

GLASSHOUSE CROPS (*Continued*)—

falls with succeeding years, but most rapidly on heavy soils where drainage is poor. Some of the lighter brick earths are among the best soils for tomatoes, and mechanical composition seems most important. The soil should be sufficiently heavy to hold the water applied during the winter until some six or seven weeks after planting, and should have sufficient drainage to remove the large quantity of water applied during the growing season.

There is little doubt that the physical factors of the plants' environment are more important than an abundance of plant foods in the soil. Indeed, manurial trials with tomatoes are singularly disappointing, while experiments with light, heat, and water supplies have proved most important.

Watering—Under normal glasshouse conditions winter flooding is a necessity; a dry subsoil is harmful, and if not wetted thoroughly during the autumn, no amount of summer watering will correct it. On medium soils, at least 240,000 gallons per acre of water should be given, in three applications. This may be too much for heavy soils, and must be reduced accordingly.

The young plant requires to draw its water supply from below, and at Cheshunt subterranean watering has proved effective during the development of the first five trusses of the crop. Surface watering should be withheld as long as possible: it tends to develop vegetative growth at the expense of the fruit. If possible it should not be given until the second truss has set. This is impossible on light soils, and subterranean watering should prove beneficial in such cases.

Overhead Damping—The setting of tomato fruits is dependent to some extent upon a warm, moist atmosphere, and the process of overhead damping with water is necessary in many localities. Wherever difficulty in setting is experienced a light, overhead damping should be tried. The object should be to leave a fine deposit of moisture on the leaves without unduly wetting the soil. A house 100 ft. long by 28 ft. wide can easily be "damped down" in five minutes.

Temperature of the Soil at Planting Time—Planting in too cold soil invariably affects the tomato adversely. The young roots are injured, and are then easily attacked by many organisms, which otherwise would do no damage. Experiment has shown that the soil temperature should be not less than 57° F. (14° C.) at planting time. Should the plants be ready before this temperature is reached, it is advisable to dib the holes, and stand the plants, pot and all, in them until the soil temperature is suitable. The plants may be left some three weeks without injury in this position.

Manuring—*Lime*—Relatively heavy dressings of lime, either as quicklime, hydrated lime, or chalk, are applied in this country, the standard dressing being at the rate of 2 tons quicklime per acre, annually. On very heavy clays this is beneficial, but most soils require no more than 1 ton per acre, and frequently a light dressing of 10 cwts. per acre is sufficient for sweetening purposes.

Lime is applied just before the last flooding, which serves to incorporate it with the soil.

GLASSHOUSE CROPS (*Continued*)—

Either quicklime or hydrated lime is best for general purposes, but as they induce too soft a growth in rich soils, chalk is preferred.

Stable Manure—Usually 30 tons per acre of stable manure is a sufficient dressing for tomato soils, and in most cases 15 tons is ample. Short material should be avoided, and it is an advantage to mix ordinary straw (wheat, barley, or oat) with it, for the tomato thrives best in soils containing a good deal of " fibre " or plant residues. Excellent results have been obtained by applications of 15 tons of stable manure and 15 tons of straw per acre. This should be dug into the ground as soon as possible after the last flooding. In this way it is acted upon by the soil bacteria, and improved as a medium for plant growth. Cow, pig, sheep, and chicken manures can only be used with extreme care; usually they are too strong for tomatoes under glass.

Green manuring is little practised and should be encouraged. Excellent results have been obtained at Cheshunt from the application of green manures, such as fresh grass cuttings, applied during December to February. Some 30 tons per acre are required.

Fertilizers—Fertilizer experiments at Cheshunt have shown that potassic and nitrogenous compounds are most important in tomato nutrition, and that phosphates are not so important. They also indicate that this plant requires a good deal of potash in the early stages of growth, and increasing amounts of nitrogen as the plant ages. If potash is not given there is a tendency towards soft growth and excessive leaf development, which adversely affects the setting and swelling of the fruits in the two bottom trusses. A plant with two good trusses of fruit rarely " bolts," as the fruit tends to restrict vegetative growth. Later, when the strain of fruit production has weakened the plant, it will take a good deal of nitrogen as a stimulant for further development. A standard base fertilizer, raked into the top 6 ins. at the rate of 30 cwts. per acre, from two to four weeks before planting, is composed of equal parts bone meal, bone flour, hoof and horn, and sulphate of potash. On new nurseries hoof and horn is usually unnecessary, and experiments suggest that applications of bone meal and bone flour need not be given more frequently than once in three years. This would reduce the base fertilizer to 10 cwts. sulphate of potash per acre each year, and a similar quantity of bone meal and bone flour every third year.

It is an advantage to apply 5 cwts. sulphate of potash per acre with the first heavy watering, which usually occurs when the second truss has set. This tends to balance the softening effect of the watering, and may be repeated fourteen days later if the plant seems too soft. When the fruit is swelling, 5 cwts. per acre of a good tomato fertilizer mixture should be applied at about fortnightly intervals. The following mixture has proved satisfactory:

6 parts meat meal.
8 parts dissolved bones.
3 parts sulphate of potash.
2 parts bone meal.
1 part sulphate of ammonia.

GLASSHOUSE CROPS (*Continued*)—

This gives on analysis 5 per cent. ammonia, 24 per cent. total phosphates, 12 per cent. soluble phosphates, and 7 per cent. potash.

Later, when vegetative growth is weakening, dried blood may be applied at the rate of 5 cwts. per acre, or the same amount of the following mixture:

1 part sulphate of ammonia.
1 part nitrate of potash.
3 parts superphosphate.
5 parts dried blood.

This has proved most useful in rejuvenating weakened crops.

It has been found that the manurial requirements of the tomato vary in relation to the weather conditions. In hot, sunny summers it requires more nitrogen and less potash than during dull, cold weather. Potash and bright sunshine both mature the tissues and induce a ripe, hard growth, while nitrogen and dull weather tend to produce soft growth. Further, it has been shown that the total weight of fruit produced per acre, in any year, varies in proportion to the total hours of bright sunshine between April 1st and September 30th (W. F. Bewley, "The Influence of Bright Sunshine upon the Tomato under Glass," *Ann. App. Biol.*, vol. xvi., No. 2, May, 1929).

Diseases of the Tomato—In view of the intensive methods of cultivating tomatoes under glass it is not surprising that they are prone to attack by many fungi and bacteria. The most important have been investigated at Cheshunt, and, with few exceptions, control measures are available. A full account will be found in "Diseases of Glasshouse Plants," by W. F. Bewley, published by Benn Bros., London. (See also Seed, Transmission of Diseases by; and Insecticides and Fungicides.)

Root Diseases—"Damping-off" of seedlings. This may be caused by *Phytophthora parasitica*, *Ph. cryptogea*, and *Rhizoctonia solani*, which occur as contaminations in some soils and water supplies, mainly those from shallow wells, ponds, and streams. Typically the seedlings become brown and constricted at soil level, and topple over. An excess of water in the soil and air, accompanied by high temperatures, increases the amount of disease. Control lies in sterilizing the soil boxes and pots by heat or formaldehyde, and in using a clean water supply. Epidemics may be checked in the case of the *Phytophthoras* by watering with a solution of Cheshunt Compound, prepared by mixing 2 parts of finely ground copper sulphate and 11 parts powdered ammonium carbonate and making a solution with water at the rate of ½ oz. to 1 gallon (Leaflet 6, *Exp. and Res. Stat., Cheshunt*).

Rhizoctonia is more difficult to control, but some forms of mercury compounds may be used, following expert advice.

Root Rot of Young Plants—This is merely another form of "Damping-off" contracted when the plants are slightly older.

Botrytis Root Rot—This disease rarely occurs except in cases of very soft plants grown under hot, moist conditions. A slightly sunken, smooth, grey patch appears on the stem near the soil, and later gives rise to a grey fungal growth of *Botrytis*.

GLASSHOUSE CROPS (*Continued*)—

Control consists of inducing dry air to circulate freely round the base of the plants. Infected individuals cannot be cured, and they should be removed, and their place replanted after spraying the soil surface with a 2 per cent. solution of calcium bisulphite, which is specific for *Botrytis*. Epidemics may be checked by spraying the soil surface and base of the plants with this compound, and by dusting the soil with dry powdered slaked lime.

"Black Dot" Disease—This may be identified by the presence of innumerable minute black sclerotia, the size of begonia seeds, on the outside of the woody tissues of the root. Frequently these black bodies are found inside the wood, which is dark brown in colour. The cortical tissues become dry and readily part from the wood. When a diseased plant is pulled out of the soil the roots offer no resistance, for they are dry and shrivelled. The disease is caused by *Colletotrichum atramentarium*, which develops most rapidly in soils rich in organic matter, and thrives in manure heaps and any straw or woody material.

Control is best achieved by soil sterilization.

Wilt Diseases—Two such diseases attack the tomato: one, which enjoys cool conditions, is caused by *Verticillium albo-atrum*, and is commonly found in Great Britain. The other, due to *Fusarium lycopersici*, favours high temperatures, and is rarely important here.

Diseased plants are frequently stunted. When temperature conditions are most favourable to the fungus the plant wilts suddenly while the leaves are still green. They may recover their turgidity at night, but the leaves ultimately wither and the plant dies. Under conditions less favourable to the fungus the process of death is slower. Actual wilting may not occur, but the leaves develop yellow blotches, and slowly dry up. Injury is due to the production of a poison by the fungus, the leaves being affected as the poison passes up the plant. A feature of a true Wilt disease, therefore, is the gradual wilting or desiccation of the leaves from the base of the plant upwards. In this way Wilt differs from root decay or mechanical injury, where the top of the plant is first affected. When a diseased plant is cut open longitudinally it will be seen that the wood is browned almost to the top of the plant.

The extent of the disease varies with the temperature, being most serious at 70° to 73° F. (21° to 23° C.). Below 59° F. (15° C.) and above 77° F. (25° C.) little damage results.

Control—Soil sterilization by heat or formaldehyde is the most effective method, but in view of the known physiological relationships of this disease the following cultural methods of control are possible:

(1) Increased temperature by suitable stoking and closing down the ventilators in the middle of the day.

(2) Shading the glass to prevent the poison being carried up the plant too quickly.

(3) Overhead damping instead of root watering.

(W. F. Bewley, "Sleepy Disease of the Tomato," *Ann. App. Biol.*, vol. ix., No 2, pp. 116-134.)

GLASSHOUSE CROPS (*Continued*)—

Stem Diseases. Botrytis Stem Rot—The lesions of this disease are the same as those in *Botrytis* foot rot, only they occur on the stem, usually at the base of a pruning snag. Infection occurs on badly pruned leaf bases; cleanly cut wounds are rarely attacked. Therefore all workers should be instructed to use sharp knives, and, when removing a leaf, to make a clean cut as close to the stem as possible. Infection is favoured by a damp stagnant atmosphere, such as occurs round the stem during the first four months of growth. To avoid this the foliage should be carefully thinned, and in this respect the removal of an entire leaf here and there is more effective than cutting away only half a leaf. The fungus spreads rapidly in the stem, and death results if the young lesions are not cut away and the wound painted with a paste of liver of sulphur or copper sulphate.

Leaf Mould—Leaf Mould or Mildew caused by *Cladosporium fulvum* is perhaps the most important disease of the tomato in this country. Infection occurs on the under surface of the leaf, and the production of a pale olive-buff, downy growth in local spots is the first sign. As the fungus penetrates the leaf a deep ochre-yellow shows on the upper surface. The original downy growth develops rapidly and changes to a tawny-olive colour, finally becoming violet-purple. Under suitable conditions the fungus spreads over the entire leaf, which soon shrivels up and hangs as dead tissue covered with dense masses of spores, which are easily dislodged and serve to infect other plants.

The extent of the disease depends upon the temperature and humidity of the air. It is most serious when the temperature is around 72° F. (22° C.), and the humidity exceeds 70 per cent. saturation. Above and below this temperature the disease is less severe, but it is not practicable to attempt a control by higher temperatures, as they are both injurious to the plant and difficult to maintain. The temperature should be kept as much below 72° F. (22° C.) and the humidity as much below 70 per cent. as possible.

Low temperatures are difficult to arrange in summer, and the control of Mildew therefore depends mainly upon the avoidance of high humidities. Ventilation must be efficient, and watering should be carried out early on fine days. Air movement alone is of great importance.

The ultimate control of Leaf Mould must come from the use of resistant varieties, of which several are already known—namely, **Up-to-Date, Stirling Castle, Maincrop,** and **Satisfaction.** These varieties are not suitable for commercial purposes, and an attempt is being made at Cheshunt to breed from them varieties in which resistance to Leaf Mould and high yielding potentiality are concomitant. Promising results have been obtained already.

Stripe Disease of the Tomato—This disease is characterized by brown longitudinal markings or stripes on the stem, by brown blotches on the foliage, and brown, sunken, irregularly shaped pits on the fruit. It is due to infection by *Bacillus lathyri*, which also causes similar lesions on many legumes, including clover, beans, vetches, and the

GLASSHOUSE CROPS (*Continued*)—

pea. The disease can be transmitted both by the soil and by the seed. Generally speaking, soft plants receiving an abundant supply of nitrogen are more susceptible to attack than hard, sturdy plants liberally dressed with potash.

Recommended control measures are as follows:

(1) The use of clean seed taken from a house where stripe has not occurred during the season.

(2) Sterilization of the soil by steam or formaldehyde.

(3) Reduced amounts of nitrogenous fertilizers.

(4) Suitable applications of sulphate of potash—namely, half a ton per acre before planting, and two dressings of 5 cwts. per acre at a fortnight's interval, starting with the first real watering.

(5) The disease is carried on the hands and knives of workers, who should be instructed to observe the regulations laid down for mosaic disease.

"Buck-eye" Rot of the Fruits—This disease occurs chiefly on the bottom truss, and occasionally on the second. It may be recognized by discoloured patches, varying in colour from grey to reddish-brown, frequently arranged in concentric circles, the whole lesion resembling the eye of a large animal. The causal organism is mainly *Phytophthora parasitica*, although occasionally *Ph. cryptogea* has been isolated from the lesions.

Infection results from the fruits touching infected soil, or when soil particles are splashed upon them through careless watering. The infection is held in a film of water between the fruits, and readily attacks them. The moist conditions at the base of the plant are favourable to the rapid development of the organisms, and the disease spreads rapidly from fruit to fruit and also along the truss stalk into the main stem, causing death of the plant.

Under moist conditions the fungus sporulates abundantly on the outside of the fruits. To control the disease, all diseased fruits must be picked and destroyed, the soil should be covered with a mulch, and watering must be carefully conducted.

The bottom foliage should be judiciously thinned to induce air circulation at soil level, and the bottom bunches tied up out of contact with the soil. The soil surface may be watered with Cheshunt Compound in bad cases, and for future protection steam sterilization or treatment with formaldehyde should be resorted to.

Mosaic Disease—The symptoms of this disease consist of a pale mottling of the foliage, varying from light green to deep yellow. The leaves are usually distorted and frequently blistered. In very young plants growing under cool conditions mottling is usually absent, but the leaves are so badly distorted and the laminæ so much reduced that they often resemble sweet-pea tendrils. Excessive blistering also occurs.

The flowers, too, become distorted and the pollen is frequently sterile.

Two forms of this disease occur: one, the ordinary Mosaic, develops only faint mottling and distortion, while the second,

GLASSHOUSE CROPS (*Continued*)—

"yellow" or "aucuba" Mosaic, produces deep yellow blotches of sharp outline. In the case of "aucuba" Mosaic the fruit is also mottled with ivory white, red, and yellow blotches, frequently to such an extent that the markings resemble those of a Paisley shawl.

The disease is highly infectious, but is only transmitted in the juice of the plant. It cannot be blown from one plant to another as is the case with diseases which produce spores on the outside of the plant. It is transmitted in juice carried on the hands, knives, and clothes of workers, and in the mouth parts of insects. It is also transmitted in the seed. Soil infection is suspected but not completely proved.

To control Mosaic disease, clean seed must be used, the houses kept free from insects such as Aphis, White Fly, and the Red Spider Mite. Infected plants which appear early in the year should be pulled up ruthlessly and burned. Later it is useless to do this, because infection has probably been carried to adjoining plants. Batches of infected plants must be isolated, and workers should be instructed to prune the healthy plants first and never to go to a healthy plant after handling one which is diseased without thoroughly washing the hands with soap and water and wiping the knife in a rag dipped in some disinfectant. Suspected soil should be steamed or treated with formaldehyde.

It is considered that clean seed is essential (W. F. Bewley and W. Corbett, "The Control of Cucumber and Tomato Mosaic Diseases by the Use of Clean Seed," *Ann. App. Biol.*, vol. xvii., No. 2, pp. 260-266).

THE CUCUMBER—The cucumber as grown in this country is parthenocarpic, the fruit being produced without fertilization. Indeed, fertilization is undesirable, because it leads to swelling of the apical end of the fruit and spoils it for market purposes. Male and female flowers are produced on the same plant, and it is customary to remove the former when trimming. Bees and large flies can cause great havoc in the houses by fertilizing the female flowers, because it is almost impossible to remove all male flowers before they open.

The chief commercial varieties are **Rochford's Improved Telegraph** and **Butcher's Disease Resister,** both spiny fruits. Cucumbers are planted in beds placed on the base or floor of the house.

Base—Observation and experiment at the Cheshunt Research Station have shown that a contaminated base is the commonest cause of injury to the cucumber crop. By causing root decay it affects the health of the plant, mottles the foliage, and prevents development of the fruits. It is essential that this part of the house should be porous, well-drained, and clean. Contaminations are produced in the beds during one year's growth, and are washed down into the base with the water. In heavy land they tend to accumulate, and very soon cause damage to the roots which grow down into the base.

A base consisting of open, gravelly soil may be freed from these contaminations for a number of years by heavily flooding with water

GLASSHOUSE CROPS (*Continued*)—

during the winter. Ultimately, however, it seems to become choked with fine particles from the beds above, and flooding is not then sufficient to cleanse it.

Contaminated bases may be cleaned by thorough steam sterilisation, using the grid system, but in heavy soils steaming must be conducted each year. Chemical sterilizers such as formaldehyde, cresylic acid, etc., have proved of little use in connection with the cucumber, and growers would be well advised to rely on steam. After a few years of thorough steaming, the base can be kept in good condition by passing steam through a 2-in. perforated pipe laid along the middle, and a few inches below the surface. Such pipes can remain in the ground permanently, and may be connected to the boiler quickly when steaming is necessary. In the absence of steaming steps should be taken to prevent roots from the beds entering the base. This can be done by shaping the base convexly, with the high part under the gutter and the low parts near the paths of adjacent houses. The shaped base should be rammed and covered with a layer of lime, 1 to 2 ins. thick, and again consolidated by ramming. A paste of blue lias lime can easily be applied over the rammed chalk surface, and a relatively thin layer will set like plaster of Paris, forming an effective barrier against the roots. At the end of the season the beds can be removed, and the final traces swept off with a brush, any cracks in the surface being treated with a little blue lias paste.

Beds—Assuming the base is open and clean, and no injury is likely to result from that source, certain precautions must be taken in the preparation of the bed to ensure a healthy crop.

The best beds are open and spongy in texture, and contain sufficient fermentable material to prevent chilling in the early stages of growth. In standard commercial practice they are prepared from stable manure and good turfy loam, in the proportion of one to two, or two to two.

Two parts of loam and one part of stable manure have been found to be a sufficiently rich mixture for general purposes.

It is an advantage to mix the two ingredients in a large heap, not later than November for use in January and through the following season, and it is convenient to place the soil and manure in layers, adding a little lime and bone meal to each barrow-load of soil. Care must be taken to keep the heap reasonably moist during the period of stacking.

Experiment has shown that the large quantity of nitrogenous material in the stable manure is not important, and that the value of this manure lies in keeping the beds warm in the early stages, and spongy through the season. In districts where clay soil predominates, serious damage results in the middle of the season by the beds becoming too compact; in such cases special care must be taken to prevent this by using only prepared compost for top-dressing purposes.

The practice of placing a thick layer of stable manure under the beds is not always a success, for it holds the moisture and creates a wet, muddy bottom to the bed, injurious to any roots which may enter it. A much better plan is to substitute a layer of well-washed clinkers,

GLASSHOUSE CROPS (*Continued*)—

or a bed of coarse hedge clippings, which, however, should not include elder clippings.

Experiments with various tough materials, such as heather roots, peat, etc., are not complete, but a good deal can be done to keep the beds open through the season by top dressing periodically with ordinary straw.

The basis of a good cucumber crop is a clean, well-drained base, and a clean open bed which does not become compact and hard during the growing season. These conditions encourage an extensive root system, and correct feeding and temperature will do the rest.

Seeds and Seedlings—It has been shown that Mosaic disease of the cucumber is transmitted in the seed, therefore it is essential that seed should be obtained from a reliable source, and that it be taken from houses where this disease has not appeared at any time during the season. (See Mosaic Disease of the Tomato.)

The seed is sown in shallow boxes, filled with a compost consisting of one part stable manure and four or five parts good loam. Germination should take place in not more than three days, and if it is delayed root injury may occur. The temperature should be held at 70° F. (21° C.). Later, the young seedlings should be transferred to size 60 pots and then to size 48 as the roots develop. The plants must be grown as strongly as possible, and to this end excessive water and heat must be avoided. The pots should be well-filled with roots before setting out in the beds.

After the plants have been set out in the beds for a week or ten days, young roots appear on the surface, and should be immediately covered lightly with compost. The first feed, consisting of 14 lbs. bone meal to each 100 ft. run of bed, is usually given about three weeks after planting, and covered with compost. Later, dressings of plain straw, stable manure, or compost can be given when required, and an occasional feed of dried blood and superphosphate at the rate of 2 ozs. per square yd., or a similar dressing of the following mixture:

1 part sulphate of ammonia.
1 part nitrate of potash.
3 parts superphosphate (30 per cent.).
5 parts dried blood.

This is an exceedingly good stimulant for plants weakened by crop production.

A good deal of acid residues accumulate in cucumber bases, and an annual dressing of caustic or hydrated lime, at the rate of 2 tons per acre, is beneficial to most soils.

The cucumber requires a good deal of nitrogen and phosphate with considerably less potash; indeed, the latter can easily be overdone.

A light dressing of nitrate of potash—about 1 oz. per square yard—will often impart a healthy green colour to pale fruits.

No accurate data are available concerning the temperature relations of the cucumber, although it is known to require a temperature around 70° F. during the early stages of growth. Temperatures must

GLASSHOUSE CROPS (*Continued*)—

always be regulated by the amount of available sunshine, for high temperatures in dull weather induce a weak, soft growth, out of all proportion to root development, and lay the foundation to much trouble later. The object of all work should be to produce a sturdy, well-rooted pot plant, and steady development of the newly planted material if a sound crop is to be obtained later.

Diseases. *Root Rot*—Cucumber roots, under commercial conditions, are attacked by a number of different fungi and bacteria, many of which have not been fully determined. Many, however, are weak parasites, which operate only under very bad conditions, and need not be considered by growers who obey the need for open, spongy beds.

(*a*) *Phytophthora parasitica*—This fungus, which commonly attacks the tomato, has been found in cucumber nurseries, where hundreds of young plants may develop Root Rot and quickly die. Infection has been traced to the water supply and to soil taken from low parts of a field. Usually the disease has been eradicated by removing diseased plants and treating the beds with a solution of "Cheshunt Compound," described on p. 503.

(*b*) *Fusarium* sp.—Various species of *Fusarium*, notably *F. oxysporum*, have been found attacking cucumber roots. Infection has been traced to turf and stable manure, and has been partially controlled by watering the beds with emulsified cresylic acid diluted with water at the rate of 1 to 2,000. Surface applications of slaked lime over a top dressing of plain loam have also proved useful.

As a rule *Fusarium* thrives under relatively high temperatures, and very hot beds, containing an excess of stable manure, are most suitable for the development of this disease. The fungus over-winters in the base, which should be steamed for the next season.

Collar Rot—Collar Rot of the cucumber is a constant feature in commercial houses, chiefly towards the end of the season. It is mainly caused by *Fusarium* sp. following wounds made by woodlice. Occasionally *Bacillus carotovorous* has been isolated from decayed collars.

Both these infections can be reduced considerably by controlling the woodlice and by keeping the base of the plant dry. Primary lesions can be healed by removing the top 2 ins. of soil from around the collar, and dusting it with a mixture of 10 parts dry, slaked lime, 3 parts finely ground copper sulphate, and 3 parts flowers of sulphur. About ten days later the collar may be earthed up in accordance with common practice.

Leaf Spots—Four fungi have been found to produce Leaf Spot on glasshouse cucumbers in this country:

(*a*) *Colletotrichum oligochætum*—This fungus causes light-brown spots and blotches on the foliage. On old spots the centre is dry and hard, like so much light-brown paper. The dry tissue cracks, but rarely falls out. This fungus also causes large, soft wounds on the fruit, ultimately covered with pink masses of spores. Similar smaller lesions may occur on the stem. The disease was common in England

GLASSHOUSE CROPS (*Continued*)—

from 1916 to 1925; it has not occurred recently to any extent. (W. F. Bewley, " Anthracnose of the Cucumber under Glass," *J. Min. Agric.*, vol. xxix., No. 586, August and September, 1922.)

(*b*) *Cercospora melonis*—This organism produces fiery, reddish-brown spots on the foliage, rather smaller and more distinct of outline than in the previous disease. The centres turn hard and brown, and frequently fall out. No lesions appear on the fruit. This disease was common in the Lea Valley from 1906 to 1915. Except in isolated parts of the country it has not been found since 1918, although there are signs of its return.

(*c*) *Phyllosticta cucurbitacearum*—This fungus produces a spot on the leaf not unlike that of *Colletotrichum*, except that the surface is covered with fruiting bodies which appear as tiny black dots. The centre of the spot does not dry out so quickly as in the previous two " spot " diseases. Lesions are not produced on the fruits.

This disease is most dangerous under conditions of low temperature, but is not usually serious.

(*d*) *Tricothecium roseum*—Occasionally, under very damp, over-fed conditions, this fungus produces a diffuse brown blotch on the foliage only. It spreads but slowly, and is not usually important.

The control of these diseases depends upon thorough winter cleaning of the soil and superstructure, as indicated previously. During the growing season they can be restricted by spraying with lime-sulphur and flour paste, or liver of sulphur and flour paste, infected foliage being removed before spraying, and later when any spots appear. Two sprayings at an interval of seven days are necessary. Spraying should be carried out after 7 p.m., and the foliage should be washed with water from a hose during the following morning. The houses must be well shaded at the time.

Gummosis—The symptoms of this disease, due to *Cladosporium cucumerinum*, are small sunken spots on the fruits. These extend rapidly, the skin breaks, and a small drop of amber-coloured gum exudes. This hardens, and the entire lesion becomes covered with a dark, olive-green, velvety growth containing numerous spores. The disease is common during cold, wet weather. It is best controlled by maintaining relatively high temperatures and a dry air. If the atmospheric conditions are not too favourable to the fungus, dusting with sulphur compounds is effective.

Wilt Disease—In this country Wilt Disease is usually due to *Verticillium albo-atrum*, details of which will be found under Tomato Wilt. This disease only occurs after very cold winters, and can be kept under control by high temperatures. Once it gains a foothold in the base it can only be eliminated by sterilization. Both steam and formaldehyde are effective in this respect.

Mosaic Disease—As in the case of Tomato Mosaic, this disease is characterized by yellow blotches on the foliage, and sometimes silver markings on the fruit. Two forms exist: one, the milder, produces distorted mottled leaves and does not affect the fruit, while the other, akin to " Aucuba " Mosaic of the tomato, is distinguished by bright

GLASSHOUSE CROPS (*Continued*)—

yellow markings and severe distortion of the leaves. At high temperatures the fruit is much disfigured by silver streaks and blotches.

The disease is mainly transmitted in the seed, which should always be obtained from clean nurseries. One infected plant in a house is sufficient to affect the entire crop, for the disease is readily carried from plant to plant on the hands and knives of the workers.

There are suggestions that the disease may be carried in the soil, and by means of the Red Spider Mite hibernating from one season to another. The former can be prevented by steam sterilization, and the mite kept under control by spraying with petroleum emulsion.

To prevent the fruit being disfigured for market purposes, the temperature should be kept below 80° F. (27° C.) as much as possible, by ventilation and shading.

"*Damping-off*" *of Fruits*—A common feature of cucumber cultivation is the failure of a large proportion of the fruits to develop further than a few inches in length. This is not a disease in the strict sense of the word, for no single organism can be blamed. It is a physiological disorder, and the sign of constitutional weakness. Normally the cucumber produces many more fruits than it can bring to maturity under existing conditions, but when the number of aborted fruits becomes excessive the crop is a failure. The occurrence of such fruits takes place usually after periods of heavy cropping and strain. It is a sign that the root action is weak, and that unsuitable conditions exist in the beds and base. The best way to check it and convert the plant into an economic fruit producer is to dry off the beds for a week, open the ventilators, and, in general, give the crop a rest. The foliage should be trimmed, all small fruits removed, and at the end of the time the beds should be top-dressed with compost and the dried blood mixture. Forcing may then proceed normally.

Insect Pests of Glasshouse Crops. (This section should be read in conjunction with Insecticides and Fungicides.) *The Tomato Moth* (*Hadena oleracea*)—The caterpillar of this moth is an important source of damage unless kept under adequate control. It destroys the foliage, but this is considered of less importance than its habit of feeding on the fruits and biting into the stems of the plants. It is no uncommon sight to find three or four fruits on a truss thus destroyed by a single larva in a night.

The following control measures are recommended (Ll. Lloyd, "The Habits of the Glasshouse Tomato Moth and its Control," *Ann. App. Biol.*, vol. vii., No. 1, pp. 66-102, 1920):

(*a*) Trap the moths throughout the growing season in jars containing poisoned bait. For this purpose 2 parts ale and 1 part thick black treacle are mixed thoroughly, and 3 fluid ozs. placed in a jar, the mouth of which should be about 2 ins. across. As much sodium fluoride as can be picked up on a sixpence should be added to the contents of the jar. The jars should be hung round the houses, on the bottom wires, employing not less than 60 jars per acre. To catch the first moths which emerge the jars must be in position before the houses are heated at the commencement of the season. The dead moths must be

GLASSHOUSE CROPS (*Continued*)—

removed as they accumulate, and the bait should be renewed every three or four weeks.

(*b*) Spray the plants with arsenate of lead while the fruit is still small. Six pounds of arsenate of lead paste, of guaranteed analysis, should be used to 100 gallons of water, to which 2 ozs. of saponin have been added. The paste should be converted to a thin cream with a little saponin water first, and then added to the main bulk of saponin water. The fluid should be thoroughly agitated when the spraying machine is filled. Plants should be sprayed in the pots, and once just after planting out. A very fine deposit on the upper surface of the foliage is best, and a whitewashed appearance of the plants should be avoided.

(*c*) Caterpillars may be trapped in folded sacks placed under the gutters on the pipes or lower wires. They should be destroyed by dipping the sacks in hot water once every three weeks.

(*d*) Market baskets should be kept away from the houses; they often contain moths and other pests.

The Greenhouse White Fly (*Trialeurodes vaporariorum*)—The White Fly is a common pest of plants under glass, and it is particularly injurious to the tomato; indeed, before control measures were available, it was estimated that one-third of the tomato crop was lost through this pest alone.

The insect sucks the sap of the plant, and secretes "honey-dew," which soon covers the surface of the foliage and fruit. Various black, brown, and green moulds grow luxuriantly in this secretion, and so much reduce the physiological processes of the plant that it is weakened considerably. Moreover, the fruits must be wiped before sending to market.

Infestations may be limited by fumigation (Ll. Lloyd, "The Control of the Greenhouse White Fly, with Notes on its Biology," *Ann. App. Biol.*, vol. ix., No. 1, pp. 1-32, 1922) or by means of a chalcid parasite (E. R. Speyer, "An Important Parasite of the Greenhouse White Fly," *Bull. Entom. Res.*, vol. xvii., part 3, pp. 301-308, 1927).

(*a*) *Fumigation*—The commonest form of fumigation against this pest entails the use of hydrocyanic acid gas, prepared by the decomposition of sodium cyanide by sulphuric acid. The gas is poisonous, and must be handled with extreme caution. Two fumigations are necessary: the first destroys all stages but the eggs, and the second is done when all the eggs have hatched out and before any of these have become adult. The interval between the two fumigations should be fourteen days in hot weather, twenty-one days in warm weather (average greenhouse shade temperature 65°-70° F. [18° to 21° C.], and twenty-five days in cool weather 60°-64° F. [15° to 18° C.]).

Hard-growing plants stand the gas better than those that are soft and sappy, but soft plants are uninjured if they distinctly require water at the time of fumigation; plants should therefore be as dry at the roots as possible. Fumigation must be carried out at or after dusk, and still, cool nights are most suitable. The houses should be measured in thousands of cubic feet. To calculate their capacity,

GLASSHOUSE CROPS (*Continued*)—

add the height to the gutter to the height to the ridge, and divide by 2. This gives the average height. To find the cubic capacity, multiply the average height by the width of the house and the product by the length of the house.

The gas is generated by dropping 1 part by weight of sodium cyanide (98 per cent. purity) into glass jars placed at regular intervals upon the paths of the houses, each jar containing 4½ parts by volume of 33 per cent. sulphuric acid. One-fifth to one-quarter of an ounce of sodium cyanide evolves sufficient gas for 1,000 cubic ft. The maximum charge of ¼ oz. per 1,000 cubic ft. is necessary for isolated houses and leaky houses in blocks, while ⅕ oz. per 1,000 cubic ft. is sufficient for tight houses in blocks.

For houses up to 14 ft. wide, ¼ oz. should be placed in each jar; for houses 14 to 20 ft. wide, ½ oz. per jar may be used; and for houses over 20 ft. wide, 1 oz. for each jar is satisfactory.

Method—See the plants are in need of water and are dry at the roots. During the afternoon place the jars containing the correct amount of acid in position on the paths, weigh out carefully the sodium cyanide for each jar, and wrap in paper.

At dusk cut off the heat, unless the night is likely to be very cold. Close the ventilators, and place the cyanide charges, fully exposed, on a piece of paper by each jar. Allow one man per house, and at a given signal let them walk down the houses tipping the cyanide from the paper into each jar. Lock the doors till dawn, then open the houses and leave for one hour before entering. Finally, collect the jars, empty the contents down a drain, and rinse them out.

Tetrachlorethane, an aromatic liquid, is more convenient to use than "cyanide," as the vapours are less poisonous to man. Further, it is unnecessary to "dry off" tomato plants when using this fumigant. On the other hand, it is more expensive and the vapours are injurious to chrysanthemums, heliotrope, and certain varieties of fuchsia and pelargonium (E. R. Speyer, "The Effect of Tetrachlorethane Vapour on Chrysanthemums," *11th Ann. Rept.*, 1925, *Exp. Stat.*, *Cheshunt, Herts.*, pp. 107-109).

To kill the adult and scale stages, 10 fluid ozs. of tetrachlorethane to every 1,000 cubic ft. are required. The eggs are not killed, and a second fumigation is necessary to obtain control. The liquid should be poured in a thin stream on the path of the house at dusk, and the ventilators need not be opened until several hours after sunrise.

A recent modification of cyanide fumigation is described by Speyer and Owen (E. R. Speyer and O. Owen, "The Fumigation of Tomato Houses with Hydrocyanic Acid Gas," *Ann. App. Biol.*, vol. xiii., No. 1, February, 1926, pp. 144-147).

An intimate mixture of 3 parts by weight sodium bicarbonate and 1 part by weight of powdered sodium cyanide is scattered upon the paths of the houses at the rate of 1 oz. of the mixture to every 1,000 cubic ft. The plants should require water at the time of fumigation.

A proprietary fumigant, "Cyanogas," has come into use lately.

(*b*) *Biological Control*—Recently it has been possible to use a

GLASSHOUSE CROPS (*Continued*)—

natural enemy of White Fly for the purpose of controlling infestations. This parasite—*Encarsia formosa* Gahan, a small chalcid wasp—was collected by Speyer, entomologist to the Cheshunt Station, from a greenhouse belonging to Mr. L. Hawkins of Elstree, Herts. It has been bred in special houses, and distributed to growers and others whose glasshouses were infested by white fly. It has proved successful in a large proportion of cases. Each female lays over fifty eggs, a single egg being deposited in each white-fly pupa. The parasite egg hatches in about three days, and proceeds to devour the White Fly pupa, the intact skin of which quickly turns black. Finally, the adult wasp cuts a hole in the roof of its prison and escapes to lay eggs in other White Fly pupæ.

The parasite is distributed to growers in the form of black parasitized scales on tomato shoots. Small numbers of shoots are made into a bunch and hung up in infested glasshouses, remaining there for a period of three weeks, during which time the minute wasp will emerge. When an average temperature of 70° F. (21° C.) is maintained, black parasitized scales may be expected to appear on infested plants from fourteen to twenty-one days after introducing the bunches. In the case of severe infestations of White Fly, the houses may be fumigated with a weak dose of "cyanide," using $\frac{1}{8}$ oz. sodium cyanide per 1,000 cubic ft. with $\frac{1}{2}$ fluid oz. 33 per cent. sulphuric acid. This will kill the majority of adult flies, and will not materially harm the parasite, leaving the young scales of the fly alive for the parasite to breed in. Alternatively, 5 ozs. of tetrachlorethane per 1,000 cubic ft. may be used except where chrysanthemums, fuchsias, pelargoniums, azaleas, hydrangeas, and cinerarias are grown.

The Red-Spider Mite (*Tetranychus telarius*)—The Red Spider Mite, abundant upon weeds and shoots, finds conditions under glass very favourable to its rapid reproduction in spring and summer, while the structure of the glasshouse affords convenient situations in which to pass the winter. It has become a serious pest of carnations, cucumbers, and tomatoes.

Although of delicate structure, it is notoriously difficult to kill by the usual methods employed against insects and other mites.

The investigations of Speyer and others at Cheshunt have led to measures whereby reasonable control can be effected. These measures may be divided into three main sections as follows:

(*a*) The destruction of the mite on the living plant during the season.

(*b*) The prevention of mass hibernation at the end of the season.

(*c*) The destruction of mites hibernating in the houses during the winter.

(*a*) *The Destruction of the Mite during the Growing Season*—This may be effected by fumigation with naphthalene or by spraying with an emulsified petroleum oil, or with a soft soap and liver of sulphur mixture.

Naphthalene was first used as a fumigant at the Cheshunt Station in 1923 (E. R. Speyer, *Ann. Rep. Exp. Res. Stat., Cheshunt*, 1923-1926). Good control of the Red Spider Mite was obtained by broadcasting

GLASSHOUSE CROPS (*Continued*)—

"Grade 16" naphthalene (pure white-flake naphthalene, which will pass a sieve of 16 meshes per inch) over cucumber beds at the rate of 3 lbs. to 100-ft. run, *i.e.*, 6 lbs. to a house 100 ft. long. The ventilators must be closed, and the air temperature kept between 74° and 104° F. (23° and 40° C.) The beds should be watered and the plants damped over shortly before the naphthalene is applied. Broadcasting should occur between 4 p.m. and 5.30 p.m. Next morning the ventilators should be opened for a few minutes to allow the vapours to escape, so that the workers may enter without inconvenience. The plants should then be damped over, and ventilators closed all day, unless the temperature runs too high for satisfactory growth. Late in the afternoon the plants should be "damped over" again, and the naphthalene should have vaporized by the following morning. Fumigations at monthly intervals provide sufficient control.

A mechanical device for vaporizing naphthalene from a lamp is described by Parker (T. Parker, "On the Control of Red Spider by Means of Naphthalene Vaporised over a Special Lamp," *Ann. App. Biol.*, vol. xv., No. 1, pp. 81-89, 1928). It has proved effective in controlling the Mite on carnations, but must be used only with extreme care in the case of tomatoes and cucumbers.

Both cucumber and tomato fruits tend to absorb the flavour of naphthalene, but it is readily eliminated by airing the fruits in a well-ventilated shed before packing.

The petroleum emulsions consist of the more refined petroleum oils, 0·86 to 0·95 specific gravity, free from unsaturated hydrocarbons, from products of oxidation, and from sulphur, emulsified with the smallest possible quantities of substances such as soft soap and a caseinate. An advantage of these emulsions is that hard water can be used for dilution.

The best effect of spraying is obtained at relatively high temperatures, and no injury to cucumber, melon, and tomato foliage has been observed from application in direct sunlight. Petroleum emulsions cannot be used on plants with waxy foliage, such as carnations, for the "bloom" on the leaves is destroyed. Also, treated plants require less water owing to conservation of moisture within the leaf. In the tomato both dropsy and *Botrytis* rot of the stems, leaves, and trusses are greatly aggravated by too frequent "damping" and the indiscriminate use of these emulsions, especially if the water requirements of the plants are not carefully regulated.

Good results have been obtained with a liver of sulphur and soft soap mixture, although it is necessary to wipe the fruit afterwards. This mixture does not aggravate "dropsy" like the petroleum emulsions.

The stock solution consists of soft soap 8 ozs., liver of sulphur 4 ozs., and rain water 4 pints. It can be kept not longer than seven days. The spray is prepared by taking ½ pint of stock solution and making up to 1 gallon with rain water.

(*b*) *The Prevention of Mass Hibernation at the End of the Season*—It is very difficult to destroy the Mite after it has reached hibernation

GLASSHOUSE CROPS (*Continued*)—

in the cracks and crannies of the glasshouse. Therefore every effort should be made to prevent masses of the Mite reaching hibernation. This can be effected by fumigating the crop with naphthalene while it is still green, and burning the plants immediately fumigation has ceased. If plants are allowed to wither and die in the houses, the Mites leave them before they can be removed.

For efficient naphthalene fumigation a sunny, warm day must be chosen, and the temperature of the house kept around 70° F. (21° C.). Naphthalene vapours are least effective under dull, cold conditions. Fumigation may be effected by scattering crude naphthalene over the ground at the rate of 2 ozs. per square yard, and keeping the houses closed and hot so long as the naphthalene remains. A better method consists of vaporizing crude naphthalene in the lamps mentioned previously.

For winter work, 1 lb. is allowed to every 1,000 cubic ft., and each lamp will hold 4 lbs. of the material. Fumigation should begin early in the day, to make full use of the sunlight and heat.

Afterwards the plants should be removed and burned, and the houses cleaned up for the winter.

(*c*) *The Destruction of Mites Hibernating in the Houses during the Winter*—Winter cleansing of the glasshouses against Red Spider is best accomplished by spraying the walls and superstructure with cresylic acid. Pale straw-coloured cresylic acid, 97-99 per cent. purity, is used either at the rate of 1 to 40 in water, or emulsified with soft soap. The emulsion is prepared by adding 8 lbs. potash soft soap to 1 gallon of the acid and heating over a fire until the soft soap dissolves. This, the stock solution, is diluted by adding 1 gallon to 39 gallons of water. A power machine should be used, and the spray delivered with considerable force into every nook and cranny of the house. A high temperature should be maintained, and the houses closed down for a week after treatment.

Staging, etc., used during propagation of the young plants, should be sprayed some six weeks before use and stored in a dry shed.

Wireworms—Three species of *Agriotes*—*A. lineatus*, *A. obscurus*, and *A. sputator*—are found attacking tomato plants in glasshouses, while *Athous hæmorrhoidalis* attacks the cucumber. The parent Click-Beetle lays her eggs in the soil from which emerge minute Wireworms. The Wireworm, or larval stage, feeds on organic matter and roots, increases in size slowly, and may take three to five years before it pupates. Finally, the Click Beetle emerges from the pupa, and the cycle is complete. Most of the damage to plants is caused by the larva or Wireworm, which in the young stage feeds on the finer roots of the tomato and other plants. The older Wireworms burrow into the base of the stem and eat their way upwards. Attacked plants may wilt through mere mechanical injury, which is the least serious form, because generally young plants are destroyed and can be easily replaced. More serious injury is produced when the wounds are not sufficiently extensive to cause direct damage, but allow infection by soil organisms, which grow in the tissues slowly. The result of such infections is not

GLASSHOUSE CROPS (*Continued*)—

felt until later in the year, when plants bearing a full crop suddenly wilt and die.

Steam sterilization destroys a large proportion of Wireworms present in the soil if it is carried out sufficiently early, and before they have migrated to the lower layers of the soil. Crude naphthalene applied by means of a mechanically driven cultivator is also valuable, but thorough admixture with the soil is necessary for the best results.

Little injury occurs during the first year of cultivation, apparently because the Wireworms prefer the turf roots in the soil to those of the tomato; serious damage may result during the second to fourth years.

The practice of trapping by means of pieces of carrot, mangold, etc., has been used with reasonable success in the past. The traps are placed midway between the plants and in the bottom of the holes before planting, and covered with a thin layer of soil. They should be examined each day, and the Wireworms removed. Recently a control has been effected by lightly rolling the surface of the soil prior to dibbing the holes for planting, and when setting out the plants, making sure that no loose soil is thrown over the ball of soil. When the soil is loose at the surface the Wireworms come near the top, and are attracted to the young succulent stems. A tight surface appears to keep them away from the plant.

Woodlice—Armadillidium speyeri is the commonest of the cucumber-house Woodlice, while *Porcellio lævis*, *Armadillidium vulgari*, and *Haplophthalmus danicus* B. Lund also occur in tomato houses. *A. speyeri* is probably the most serious of these pests, which damage the roots and base of the stems of many plants, especially the cucumber and tomato.

The following measures are recommended for ridding glasshouses of this pest in the winter (E. R. Speyer, *8th Ann. Rept. Exp. Res. Stat., Cheshunt*, p. 48).

(*a*) Remove the beds in the case of cucumber houses as far away from the houses as possible.

(*b*) Flood the soil heavily after breaking up the lumps with water; this will drive the Woodlice out of the ground, and cause them to rise to the surface and swarm up the walls.

(*c*) Spray the walls and soil surface immediately with 1 gallon of the following mixture in 49 gallons of water:

8 lbs. potash soft soap.
1 gallon cresylic acid.
½ lb. pure naphthalene.

These should be heated in a bucket till the soap is melted and the naphthalene completely dissolved.

During the growing season control may be effected by broadcasting an intimate mixture of 1 lb. commercial Paris green powder and 28 lbs. dry bran, at the rate of about ½ oz. per square yard. For pot plants on staging a little of the bait should be sprinkled over each pot, in addition to broadcasting under the staging.

GLASSHOUSE CROPS (*Continued*)—

Watering should be carried out before applying the bait, which is effective chiefly when dry.

Eelworm (*Heterodera radicicola*)—The Root-Knot Eelworm has proved a serious pest of both cucumbers and tomatoes under glass. Infested plants usually fail to develop normally, show yellowing of the upper leaves, and ultimately wilt. The roots bear innumerable nodules or swellings, sometimes as large as grapes. Such swellings have developed as the result of infection by the Eelworms.

The female enters the root and lays eggs some twenty-five days later. Under most favourable conditions these may hatch within a few days. Ultimately the root nodules decay, and the Eelworms pass out into the soil. The pest exists as a contamination in some soils, having been introduced probably through the medium of manure or drainage water from infected areas. It is extremely difficult to control, but the best results have been obtained by deep sterilization with steam. Chemical treatment has invariably given such erratic results that it cannot be relied upon as a means of freeing soil from this pest. (For methods of preservation of glasshouse products by refrigeration see Refrigeration.)

W. F. B.

GOOSEBERRY—See Soft Fruits, under Fruit.

GRAIN, COMMERCIAL STANDARDS OF—The movement overseas of approximately 1,600,000 quarters of wheat weekly, besides other grain from the surplus-producing countries of the world to those insufficiently supplied by their own production, is accompanied by certain risks, independent of price changes on the world's markets, of sufficient fundamental importance to commerce to require administrative machinery to deal with them. These risks relate to the quality of the consignment, its condition on loading and at the port of discharge, and its change in weight during the voyage.

The word "quality" in this connection is used in a restricted sense well understood in the grain trade. Quality here means weight per bushel, and freedom from broken, damaged grains, weed seeds, and other kinds of cereals than that constituting the bulk. Indeed, it may be looked upon as including those factors which depend on the season and on the degree of skill and care exercised by the cultivator from seed time to harvest. From the viewpoint of the grain trade the inherent qualities of the grain, determining in the main its baking or brewing or feeding value, are covered by its "description," such as "Dark Hard Winter" or "Rosafe" wheat, and such descriptions are never abused. The word "condition" is, again, carefully distinguished from "quality." It refers to the degree of deterioration of the grain from its original soundness, and is governed in the main by the initial moisture content of the grain and the length of time and physical conditions of the place of storage.

In the absence of entirely dependable standards of quality against which purchases may be made and well-established practice as to how to deal with grain arriving out of condition and/or weighing less on discharge than the Bill of Lading weight, a purchase of wheat abroad would be hazardous even apart from market risks.

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—

Quality Clauses of the London Corn Trade Association Contracts—Each of the contracts of the London Corn Trade Association contains one or more clauses denoting the standard of quality in accordance with which the sale is made. When these clauses present alternatives, as is frequently the case, those not applying to the particular sale are struck out. The clauses differ slightly from contract to contract, even when their sense is much the same. Taken from the seventy-five contract forms they fall into three groups. The sale may be:

(1) On sealed sample;
(2) On f.a.q. terms; or,
(3) On "certificate final" terms.

Fair Average Quality (*f.a.q.*)—When a sale is made on these terms the grain is guaranteed to be "of fair average quality of the season's shipments at time and place of shipment," and in some f.a.q. contracts, notably those dealing with Argentine grain, the words "of the under-mentioned weight" are added, the weight referred to being the "weight per bushel" or the "natural weight," as it is called in the grain trade. The clause relating to the natural weight reads as follows:

> "Natural weight of ...... lbs. per bushel guaranteed at time and place of loading or discharge to be ascertained and determined according to the rules of the London Corn Trade Association for the description of grain sold."

A very considerable quantity of grain is sold on f.a.q. terms, particularly grain from the Argentine, from Russia and the Black Sea, Australia and India. Most of the standards are made up by the London Corn Trade Association, while those which are not, but are made in the country of production, those from Australia for instance, are available in the Association's headquarters above the Baltic Exchange.

The setting up of the f.a.q. standards in London is undertaken at frequent intervals by the Sectional Committees of the London Corn Trade Association, each Committee being responsible for the establishment of the standards for grain from the exporting country with which its members are engaged in commerce.

Contracts for the sale of grain on f.a.q. terms, where the standard is made in London, require the contracting parties to sample the grain at the port of discharge, and to forward the samples to London for the purpose of establishing the standard. Rules governing the sampling of cargoes and parcels for this purpose are printed on Form 66 of the London Corn Trade Association. According to these rules a jointly sealed sample of 2 bushels of wheat for quantities of less than 1,000 tons, and 4 bushels for larger quantities, must be sent to London for this purpose. On arrival at the London Corn Trade Association's rooms in St. Mary Axe, the 4-bushel sample (say 250 lbs.) of wheat is emptied upon the floor of the grain standards room, thoroughly mixed with wooden shovels, and weighed with formality and care on a 20-litre Schopper grain balance. It is customary to weigh five separate lots

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—

of 20 litres, and to average the five readings. This figure incidentally serves as the basis for the allowances made for the departure, if any, from the natural weight guaranteed by contract. But we are considering it now in connection with its use in the establishment of the f.a.q. standard. For this purpose small representative samples, taken from each of the bulk samples so dealt with, are displayed in small open wooden bowls in the order of their natural weights in the Association's rooms. For each cargo or parcel of each kind of grain sold f.a.q. which left the ports of the district concerned during a given month there is thus a corresponding representative sample. Its weight per bushel and the quantity it represents are written up. Members of the Standards Committee of the Association for the particular grain now review these samples, grouping them according to their natural weights in two or three groups, rejecting from each group any sample which does not fairly come within the quality and condition of the group. The standards are then made up by the officials of the Association, one for each group, by taking quantities of each from the bulk samples of grain to be included in the standard proportional to the size of the shipments they represent, and thoroughly mixing them. Each of the standards so made up is then weighed for natural weight and the figures published to the trade. Thus, on October 30, 1930, the Argentina Committee made the following f.a.q. standards for wheat shipped during the month of July, 1930:

ARGENTINE WHEAT.

	Kilos per Hectolitre at Time of Discharge.		*Lbs. per Imperial Bushel at Time of Discharge.*
1	76·6	River Plate wheat of the provinces of Sante Fé and/or Cordoba	61·412
2	75·45	Bahia Blanca Barletta and/or Russo wheat	60·490
3	76·65	Bahia Blanca Barletta and/or Russo wheat	61·452

It is an essential part of the f.a.q. system that the buyer may submit for the decision of arbitrators the assessment of the difference expressed in pence per quarter, between the quality of the grain delivered to him under the contract and that of the standard set up as above.

This decision is arrived at by two arbitrators, one representing the buyer and one representing the seller, who compare samples of the delivered grain with the standard against which it was sold. The samples for this purpose are taken during discharge apart from those taken for the purpose of ascertaining the natural weight and for establishing the standards. Samples of 2 lbs. for each 50 tons in the

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—
case of cargoes, and 1 lb. for each 20 tons in the case of parcels, are required by the rules printed on Form 71 of the Association for the purpose of arbitration.

Allowances for differences between natural weight guaranteed under the contract and that of the actual delivery are made automatically, according to the schedules printed on Forms 66/70, and arbitrators take into consideration allowances made under this head in deciding allowances on inferiority as compared with the f.a.q. standard.

The establishment of the f.a.q. standard in Australia is described by G. L. Sutton, in Bulletin 188 of the Department of Agriculture for Western Australia, 1926, in which also the inconveniences of an f.a.q. standard made in the country of origin are discussed.

Certificate Final as to Quality—Overseas buyers of American and Canadian grain accept the grading of the producing country without question, the terms of sale being known as "certificate final as to quality." The certificate referred to is that issued by the Department of Trade and Commerce of the Dominion of Canada, or by the Chamber of Commerce or Produce Exchange of the port of export in the United States, and certified in this case by an Inspector licensed by the Federal Government to perform the operations of grading.

The establishment of grades for grain depends in the first instance on the classification of the commercial varieties of grain into commercial classes, each with an appropriate "description," and then the establishment of a specification for each grade within each class based on the measurement of those characteristics known to govern quality (in the restricted sense here used)—namely, weight per bushel, moisture content, percentage damaged kernels, percentage foreign material, and percentage grain of other classes—to which any particular consignment must conform to be admitted within the grade.

Thus, the classes of American wheats and the grade requirements for each, as determined by the United States Department of Commerce, are as follows:

Class I.—Hard Red Spring Wheat. Subclasses: (*a*) Dark Northern Spring, (*b*) Northern Spring, (*c*) Red Spring.

Class II.—Durum Wheat. Subclasses: (*a*) Amber Durum (*b*) Durum, (*c*) Red Durum.

Class III.—Hard Red Winter Wheat. Subclasses: (*a*) Dark Hard Winter, (*b*) Hard Winter, (*c*) Yellow Hard Winter.

Class IV.—Soft Red Winter. Subclasses: (*a*) Red Winter, (*b*) Western Red.

Class V.—White Wheat. Subclasses: (*a*) Hard White, (*b*) Soft White, (*c*) Western White.

The schedule of grade requirements is given in the table on p. 523.

Wheat is also sold on sample, and sample graded wheat is wheat which has some unusual characteristic which is not fairly indicated by the specification of the grade. As for condition, the official standards include a statement of which the following is typical:

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—

(1) The wheat in Grade Nos. 1 to 4 inclusive shall be cool and sweet.

(2) The wheat in Grade No. 5 shall be cool, but may be musty or slightly sour.

Grade Number.	*Minimum Weight in Lbs. per Winchester Bushel.*		*Moisture.*		*Damaged Kernels.*		*Foreign Material other than Dockage.*		*Wheats of other Classes.*		
	Class I.	*Classes II., III., IV., and V.*	*Classes III., IV., and V.*	*Classes I. and II.*	*Total per cent.*	*Heat damaged per cent.*	*Total per cent.*	*Matter other than Cereal Grain.*	*Total per cent.*	*A.*	*B.*
1	58	60	13·5	14·0	2	0·1	1	0·5	5	2	2
2	57	58	14·0	14·5	4	0·2	2	1·0	10	5	3
3	55	56	14·5	15·0	7	0·5	3	2·0	10	10	10
4	53	54	15·5	16·0	10	1·0	5	3·0	10	10	10
5	50	51	15·5	16·0	15	3·0	7	5·0	10	10	10

(*A*) Percentage Durum permitted in Class I. or III.; also percentage Soft Red Winter and/or White wheat in Class II. (*B*) Percentage Durum in Class IV. or V.

In the United States the grading of grain takes place at approximately 500 centres. From the point of view of the importer in Europe the grading undertaken at the ports is chief in importance.

The grading service is supervised by a "project" of the United States Department of Agriculture known as the Federal Grain Supervision, with administrative headquarters at Washington and field headquarters at Chicago.

Offices and laboratories of this "project" are maintained at all important grain centres, and in particular at all export points. The function of the Federal Grain Supervision is:

(1) To ensure accurate and dependable grading by the Inspectors.

(2) To take appeals against the Inspectors' grading.

(3) To ensure the uniform application of the grading schedule as between one centre and another.

(1) At the present time (1930) the Federal Grain Supervisors duplicate about 25 per cent. of the sampling and of the actual laboratory grading undertaken of the Inspectors. Thus, Kansas City duplicates about 10 per cent. of the work; Omaha, about 12 per cent.; and Gulf Ports, 100 per cent. of the sampling and grading of the inspectorate.

(2) *Appeals*—When a seller is dissatisfied with the grade assigned

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—
by the Inspector or with any qualification of the grade made by the Inspector, such, for instance, as total damage, smut, odour, flavour, and appearance, so-called interpretative factors, he may appeal to the Federal Grain Supervisor, who samples the grain and analyses it in accordance with the prescribed methods of the Department. His certificate supersedes that of the Inspector, which is revoked. The sample examined by the Grain Supervisor, together with his findings, is sent in due course to field headquarters, referred to next.

(3) *Steps to Ensure Uniformity in the Interpretation of the Grade*—Each day the Federal Grain Office in each city where such an office is established despatches to Chicago a proportion of its daily work in the form of 5 or 6 samples, each of one kilogram, together with the Supervisor's finding in respect of natural weight, moisture content, dockage, total damage, heat damage, foreign material, broken grain, other grain, and the presence of weevil, smut, etc.

The purpose of the despatch of these samples is to provide a means of guaranteeing the uniform application of all the factors by one board, namely, the Board of Review. Personal judgment enters into the question of grading at certain points—that is, on interpretative factors and in order to ensure that grain graded at Newport News, say, shall conform strictly to that graded at Galveston, such daily review at Chicago is found necessary and sufficient.

Inbound grain at the elevator at the seaboard is thus sampled and graded. This provides the elevator company with detailed particulars as to—

(*a*) The weight per bushel.
(*b*) The determining factor of the grade.
(*c*) The percentage dockage, total damage, foreign material, etc., in the wheat.

It is then taken into storage, and the main characters of the wheat are written up in the operating room in a space on a board representing the plan of the elevators. A typical entry would be:

	N.W.	*M.*	*T.D.*	*F.M.*
1 H.W.	60·2	11·7	1·0	0·8

To execute orders for grain of a stated grade and description it is sufficient (in the United States, although not in Canada) if the elevator delivers grain which satisfies the minimum requirements of the grade, as prescribed by the Grain Standards Act, and given above. The elevator company then blends its wheat by the use of the above determined factors, so that the wheat delivered does not overstep or fall short of these minimum requirements. Then, as the grain is delivered into the hold of the vessel, samples are taken continually by means of a "pelican" sampler which cuts through the stream of grain, and the samples are continually analysed mechanically to determine finally the factors on which the grade of the wheat is based for the purpose of the certificate on which it is sold overseas.

In Canada, grain moving eastwards to the storage ports of Fort

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—

William and Port Arthur is held up at Winnipeg while each car is sampled. By the time it arrives at the storage ports the grade of each numbered car load which has been determined in Winnipeg is known, and the grain can be unloaded into the elevator. Grain moving eastwards towards Vancouver is similarly sampled at Calgary or Edmonton.

The standards established under the Canada Grain Act of 1912, and amended in 1929, comprise statutory grades, the definitions of which are laid down in the Act, and commercial grades, the characters of which change yearly according to the exigences of the crop.

The statutory grades for spring wheat grown in the prairie provinces are as follows:

No. 1 Manitoba Hard wheat shall include all varieties of Hard Red Spring wheat equal in value to "Marquis" wheat; shall be sound and well cleaned, weighing not less than 62 lbs. to the bushel; shall contain 75 per cent. of hard red vitreous kernels.

No. 1 Manitoba Northern wheat shall include all varieties of Hard Red Spring wheat equal in value to "Marquis" wheat; shall be well matured and well cleaned, weighing not less than 60 lbs. to the bushel and practically free of damaged kernels and foreign grains; shall contain 60 per cent. of hard red vitreous kernels.

No. 2 Manitoba Northern wheat shall consist of Hard Red Spring wheat equal in value to "Marquis" wheat; shall be reasonably sound and reasonably clean; weighing not less than 58 lbs. to the bushel, and shall contain 45 per cent. of hard red vitreous kernels; or may be composed of soft varieties of Red Spring wheat, which shall be sound, reasonably clean, weighing not less than 60 lbs. to the bushel, and contain 60 per cent. of red kernels; may contain Amber or Red Durum wheat, singly or in combination, up to 1 per cent.

No. 3 Manitoba Northern wheat shall consist of Red Spring wheat varieties which are excluded from the preceding grades on account of damage; shall be reasonably sound and reasonably clean, of fair milling quality, weighing not less than 57 lbs. to the bushel, and may contain Amber or Red Durum, singly or in combination up to 3 per cent.

It will be observed that the determination of the weight per bushel of grain underlies the establishment alike of the grade and the f.a.q. standard. It is not, therefore, surprising to find that considerable attention has been paid to the question of weighing a bushel of grain accurately.

Four sets of units are used in international trade, viz., lbs. per imperial bushel, lbs. per Winchester bushel, kilograms per hectolitre, and poods per chetwert. Some slight confusion may result from the difference in capacity of the two bushel measures. The imperial bushel has a volume of 2218·19 cubic ins. (the volume of water at 60° F. which weighs 80 lbs.), while the older Winchester bushel used in the United States and in Canada has only 2150·42 cubic ins., so that the latter is 0·969 of the former—that is, about 3 per cent. smaller. Thus, 60 lbs. per Winchester bushel is 61·9 lbs. per imperial bushel.

On the metric system the customary figure is the weight in kilograms

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—

per hectolitre (100 litres). Since 1 hectolitre = 2·7512 bushels and 1 kilogram = 2·20462 lbs., weights in kilos per hectolitre may be converted into lbs. per imperial bushel by multiplying by 0·8012. Thus, 78 kilos per hectolitre = $78 \times 0{\cdot}8012$ = 62·49 lbs. per imperial bushel. These equivalents are printed on Form 73 of the London Corn Trade Association.

The accurate determination of the bushel weight of grain is difficult unless a standard instrument is employed, uniformity of procedure adopted, and care is exercised. The difficulty of ascertaining the natural weight accurately arises from five possible sources of error associated with each of the following items: (*a*) a measure of known volume is (*b*) filled with grain, (*c*) levelled off so that the measure is full. The filled measure is (*d*) to be weighed, and (*e*) its weight to be multiplied by some factor to bring it to the weight per bushel.

(*a*) The volumes in common use are 20 litres, on an instrument known as the Schopper scale, the standard used by the London Corn Trade Association; 1 imperial bushel, the volume used for grading wheat under the Liverpool Corn Trade Association's Contracts for Future Delivery, on an instrument known as the McGuirk machine; 1 Winchester quart, customarily used throughout North America, on an instrument known as the Boerner weight per bushel apparatus. Smaller instruments are also in common use in the grain trade—notably ¼ litre and 1 litre by Somner and Runge, and one of ½ pint capacity—none, however, in the establishment of standards.

(*b*) The operation of filling the measure with grain leads to a variety of results according to the method adopted. Consequently, the instrument must be so constructed that no variation in the manner of filling is possible.

Under this heading comes a source of error in arriving at the bushel or hectolitre weight when a fractional part of either is weighed. For instance, 20 litres of wheat weighed on the Schopper balance weigh, say, 1,450 grams. The hectolitre weight should therefore be $1{,}450 \times 5 = 7{,}250$ grams.

Actually the weight observed by weighing the whole hectolitre is 72·80 kilos. The reasons for the difference between the observed figure and that obtained by simple multiplication are that the grain packs differently: (1) according to the quantity present and the consequent pressure to which it is subjected; and (2) according to the area of the walls of the container, where it naturally lies differently from its position within the mass.

These differences have been investigated by the Kaiserlichen Normal Eichungskommission, published in tables entitled "Tafel zur Vergleichung der Angaben der eichfähigen Getreideprober." These tables are invariably used in connection with the ascertainment of the natural weight of grain with the 20-litre Schopper scale, and with the 1 and the ¼ litre Sommer and Runge apparatus, the first-named of which is the standard instrument of the London Corn Trade Association. These tables give the observed weights of wheat, oats, barley, and rye per ¼ litre, 1 litre, 20 litres, and 100 litres, tabulated side by side for a

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—

complete range of natural weights of each cereal, together with the equivalents in lbs. per imperial bushel, lbs. per Winchester bushel, and poods per chetwert.

The divergence between the observed and calculated weights is, however, less than 0·5 kilos per hectolitre, *i.e.*, 0·4 lb. per bushel within the limits expressed in the following table, using the instruments named above:

	¼ *Litre.*	1 *Litre.*	20 *Litres.*
WHEAT.			
Range, 53-66 lbs.	58-65 lbs.	56·25-64·2 lbs.	
RYE.			
Range, 52-64 lbs.	53 lbs. and upwards	52-61 lbs.	
OATS.			Always.
Range, 31-48 lbs.	38·5 lbs. and upwards	42·6 lbs. and upwards	
BARLEY.			
Range, 40-60 lbs.	44·8 lbs. and upwards	45·6 lbs. and upwards	

It follows, therefore, that when an accuracy of 0·4 lb. per bushel is sufficient, a good ¼ litre (½ pint) apparatus is satisfactory, except for grain of inferior quality, or in the case of wheat and rye of quite superior quality. For accurate correlation of the kilos per hectolitre or lbs. per bushel with the weights obtained by using the smaller instruments, the tables above referred to must be used.

(*c*) Striking the excess of grain from the brimming measure is performed either by hand; with a striker as in American grading, with the Boerner apparatus, or in the McGuirk machine; or automatically in the Schopper and Sommer and Runge machines.

(*d*) The weighing is carried out by suspending the measure at the end of the arm of a balance. In the Schopper and Sommer and Runge instruments the arms are equal and weights are placed on the other balance pan equal to the weight of the grain in the measure, or else a steelyard type of balance is used, so that weight per bushel is read directly. Here it is necessary to check the graduation of the instrument.

Detailed descriptions of the Louis Schopper balance, the Boerner apparatus, and of the McGuirk machine, together with the methods of working, are given in "Grain" (S. J. Duly, Oxford University Press, London, 1928).

Condition—The risk that the grain bought from overseas may arrive out of condition is provided for by the following clauses.

Each contract states "shipment in good condition," and either:

> "Condition guaranteed on arrival (subject to any country-damaged grain, in the fair average quality of the season's crop); slight dry warmth not injuring the grain not to be objected to, but damage by sea water or otherwise to be taken by buyer with an allowance for deterioration (except for country-damaged as

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—

above) calculated on a percentage based on contract price to be fixed by arbitration in London."

These are known as "rye terms." Or:

"Shipment in good condition, but tale quale as regards condition on arrival."

These are known as "tale quale" terms.

Where grain is sold on *rye terms* the buyer receives allowances from the seller for deterioration during the voyage, the amount being decided by arbitration. On the other hand, when grain is sold on "tale quale" terms the buyer has no recourse against the seller in the event of the grain arriving in a damaged state, unless he has indisputable evidence that the grain was not shipped in good condition.

The chief factor controlling the condition of grain during storage is the percentage of moisture in the grain, while the kind of grain, the length of time in store, the average temperature and humidity of the air which has access to it, govern the extent of the deterioration if any. No direct reference to the moisture content of the grain is made in London Corn Trade Association's contracts, although this figure is of importance to millers, seeing that flour is sold with a moisture content of 15 per cent. The only way in which the moisture content is taken into account in such contracts is indirectly. Thus the maximum limits of moisture content for each grade of grain graded in the United States are fixed, so that when wheat is bought on United States certificate, the maximum allowable moisture content is prescribed. When wheat is sold on f.a.q. terms, the moisture content is indirectly taken into account in the natural weight, for the natural weight falls by about 0·7 lb. for each additional per cent. of moisture within the small limits of variation of moisture customary in commerce.

There is no universally accepted method of determining the moisture content in cereals. The method in widest use is that of Brown and Duval, which is operated as follows: One hundred grams of wheat are placed in a round-bottomed flask having a bent delivery tube which conducts the water vapour through a condenser surrounded by cold water. One hundred and fifty grams of mineral oil are poured on the wheat, and the flask closed with a rubber cork through which passes a Centigrade thermometer. The flame of a Bunsen burner (or other source of heat) is adjusted so that a temperature of 180° C. is reached in twenty minutes. By this time all the water in the wheat will have been driven off and condensed. It is collected in a glass measuring cylinder graduated in cubic centimetres, so that the reading expresses the pecentage moisture in the grain directly.

It is important that an apparatus of standard specification should be employed in this determination.

This method is employed in North American grading and in regulating the moisture content in Argentine shipments. It was standardized

GRAIN, COMMERCIAL STANDARDS OF (*Continued*)—
against the water-jacketed oven, and thus gives low results compared with alternative methods.

Change in Weight of Grain during the Voyage—The third risk mentioned at the head of this article relates to the change in weight (usually a loss) of grain during shipment. The change is due to natural causes, such as the drying-out of the grain during the voyage or its absorption of moisture. There is also an inevitable natural loss in weight due to the carbon dioxide given off by the wheat in respiration, but this is entirely negligible as long as the grain remains in good condition. Thus, the Reports of the Grain Pests War Committee of the Royal Society show the weight of carbon dioxide given off from dry wheat containing 10·2 per cent. of moisture to be of the order of 0·007 per cent. of the grain in five months. On the other hand, the loss in weight due to the evolution of carbon dioxide and moisture when grain goes out of condition may be considerable.

Handling, and cumulative errors in weighing, also introduce differences in weights between the weight loaded and that discharged. The London Corn Trade Association allow the receiver to deduct 1 lb. per 1,000 lbs. from the weight of grain as ascertained on discharge when a "beam scale" is used, on the ground that to turn this scale slightly, as is customary, more than the quantity weighed is necessary at each draft. This allowance is known as draftage.

The following is a list showing the percentage "shrinkage" (loss in weight) customary on consignments of wheat to the United Kingdom:

Kind of Wheat.	*Place of Origin.*	*Number of Shipments.*	*Average Percentage Loss in Weight.*
Manitoba	Vancouver	9	0·19
Western White	Portland, Ore.	12	0·30
Plates	Argentine	Large number	0·40
Two Hard Winter	U.S. Atlantic Seaboard	8	0·20
Western Australia	1924-5	254,000 tons	0·446
,, ,, ...	1925-6	133,000 ,,	0·549
,, ,, ...	1926-7	350,000 ,,	0·382
,, ,, ...	1927-8	315,000 ,,	0·220
South Australia	1925-6	40,000 ,,	0·009
,, ,, ...	1926-7	110,000 ,,	(0·001 surplus)
,, ,, ...	1927-8	50,000 ,,	0·149

Most of the London Corn Trade Association's contracts provide that the receiver shall only pay for the net weight delivered to him. The seller thus usually bears the loss due to natural shrinkage. In the case of North American wheat shipped in parcels to Liverpool and Manchester, the shipper guarantees the outturn only to within 1 per cent. of the bill of lading weight, so that the receiver bears the loss due to any shrinkage up to 1 per cent.

S. J. D.

GRAPES—For Methods of Preservation by Refrigeration, see Refrigeration.

GRASSES, THE BREEDING OF HERBAGE—Although relatively little work on the breeding of herbage grasses had been carried out before the beginning of the present century, the literature of the subject is already too extensive to be fully reviewed within the scope of a short article, and the references given cannot, therefore, be considered to cover the entire field. The number of species upon which a certain amount of work has been done is also large. The most important species, however, are timothy (*Phleum pratense*), cocksfoot (*Dactylis glomerata*), perennial rye-grass (*Lolium perenne*), and the fescues (*Festuca* spp.), and since all these, as well as tall oat-grass (*Arrhenatherum elatius*) and meadow foxtail (*Alopecurus pratensis*), and Italian rye-grass (*Lolium multiflorum*), are very similar in their flowering and breeding characteristics, to deal with each species independently would lead to unnecessary repetition. All these agree in being normally wind-pollinated. Further work on certain important species such as the meadow grasses (*Poa* spp.) and crested dogstail (*Cynosurus cristatus*) is necessary before it can be asserted that the same breeding methods should here be applied, while it is already known that field brome grass (*Bromus arvensis*) and *Poa fertilis* are highly self-fertile (H. N. Frandsen, "Undersøgelser over Bestøvnings- og Befrugtningsforhold hos nogle Graes- og Baelgplantearter paa Forsøgsstationen ved Tystofte," *Tidsskrift for Planteavl*, 23; 442-486, 1916), and that *Agropyron tenerum* is normally self-pollinated (L. E. Kirk, "Breeding Improved Varieties of Forage Crops," *J. Am. Soc. Agron.*, 19; 225-239, 1927*a*). None of these three species is as yet of importance in this country, and little reference will therefore be made to species of this type.

It cannot definitely be ascertained when the first attempt to produce improved types of herbage grasses was made, but active work on perennial rye-grass was in progress in this country more than a hundred years ago, and several new and distinct strains of superior merit were then produced (G. Sinclair, "Hortus Gramineus Woburnensis," London, 1825). These strains, as such, have disappeared. Very possibly they became merged in the ordinary commercial types of that period, or they may be the main basis of our present-day cultivated type.

It is possible that further attempts of a similar kind were made either by individuals or by seed firms in the interval, but the next recorded step in herbage grass breeding appears to have been taken by Hays, who started work on Timothy in Minnesota about 1889 (Fruwirth, "Zur Technik der Grasszüchtung," Beiträge zur Pflanzenzucht, 99-133, 1913; A. Boss, *J. Heredity*, 20; 497-509, 1929). Körnicke, perhaps somewhat earlier, since his results were published in 1890 (Frandsen, *loc. cit.*, Fruwirth, "Handbuch der landwirtschaftlichen Pflanzenzüchtung," ii., Berlin, 1924), had studied the flowering characteristics of some of the grasses, and this appears to be the starting point of the more practical work which was later developed by Fruwirth and others on the Continent (K. Weller, "Der Stand und die Bedeutung

GRASSES, THE BREEDING OF HERBAGE (*Continued*)—

der Futterpflanzenzüchtung in Suddeutschland," *Mitt. d. deut. Landw. Gesell.*, 46, 1928, reprint). Serious grass-breeding work was commenced in Denmark and in Sweden early in the present century, but in our own country any work done before or during the war was individual and perhaps spasmodic. It should be mentioned, however, that Garton turned his attention seriously to grass breeding about 1893, but his methods were entirely different from those adopted by most other workers (A. N. M'Alpine, "The Production of New Types of Forage Plants—Clovers and Grasses," *Trans. Highland and Agric. Soc., Scotland*, Ser. 5, 10; 135-165, 1898).

The Aims and Purposes of Breeding—Seed yield in the herbage grasses is of first importance only within relatively limited areas where the production of seed for the market is an industry in itself. The vast majority of those interested in herbage grasses consider first of all the type of produce obtained, and seed yield to them is of importance only in so far as it affects the market price. It follows, therefore, from the breeder's point of view, that his aim should be to produce strains which are in some respects, and for the use of the average farmer, superior to existing strains, while they should yet be capable of producing seed in sufficient quantity that the price is not prohibitive. (See Grass Seed, Production of.)

Where the same species is used for different purposes, it may be necessary to produce "special purpose" strains, such as, for instance, a strain particularly useful for hay production, and another for grazed pasture purposes. Or it may be necessary to produce strains in which a particular desirable characteristic is especially developed, or, on the other hand, where it is sought to reduce a prevalent but undesirable character such as the widely creeping habit of *Bromus inermis* (L. E. Kirk, "Self-fertilization in Relation to Forage Crop Improvement," *Sci. Agric.*, 8; 1-35, 1927*b*).

The need for improvement has been realized mainly through the fact that ordinary commercial seed of the more important species does not, in fact, adequately fulfil the rôle expected of it. In this country this has been most obvious in laying down land to long duration leys or permanent pasture (R. G. Stapledon and T. J. Jenkin, "Pasture Problems: Indigenous Plants in Relation to Habitat and Sown Species," *J. Agric. Sci.*, 8; 26-64, 1916; T. J. Jenkin, "Pasture Studies: Some Results," Bangor, 1919), but it may be observed that in most other countries ordinary commercial strains were not regarded as satisfactory even as hay producers. Thus, in America with Timothy, in Denmark with Timothy, cocksfoot, rye-grass, and meadow fescue, and in Sweden with the same species, the first attempts at improvement were in the direction of better hay types. It is true that at Svalöf, in Sweden, Witte ("Breeding Timothy at Svalöf," *J. Heredity*, 10; 291-299, 1919*a*) had realized that the characteristics of a good pasture-type plant were not the same as those of a good hay type; but even at this station serious work on the breeding of pasture-type plants was not taken in hand until 1928, although much material of

GRASSES, THE BREEDING OF HERBAGE (*Continued*)—

this type had been collected and had been partially studied since about 1904 (Anon., "The Svalöf Plant Breeding Institute: Short Information for Visitors," Hälsingborg, 1929).

The desirable characteristics of improved types have been enumerated by various writers. For hay purposes they are mainly:

(1) Increased yield at mowing,
(2) Good spring growth.
(3) Good aftermath.
(4) Continued productivity over the whole period of the ley.
(5) A high proportion of fresh green leaf to stem at mowing time.
(6) High persisting capacity in relation to the length of the ley.

Thus, yield as hay is not alone the criterion, for the quality of the hay also enters into consideration. Persistency again involves not only the inherent longevity and regenerative powers of the plant itself, but also its capacity to withstand adverse climatic conditions and disease attacks.

For pastures, persisting capacity in all its aspects is even more important, since the leys are usually of longer duration. While, however, for hay an abundance of leaf *on the stems* is necessary in order that the hay may be leafy, for grazed pasture purposes leaf should be borne in abundance at the base of the plant—that is to say, the non-flowering tillers should be numerous and leafy, so that a dense leafy turf is produced. The herbage should, of course, be palatable, and the plants should possess rapid regenerative powers so that only a short resting period is required between two grazing periods. As far as possible also a long growing season is important, but to what extent all desirable characteristics can be combined in a single strain remains to be seen.

The Material Available—The possibility of combining many desirable characteristics in a single strain depends upon whether variations in these directions exist or can be produced. Garton, who had been trained in the domain of cereal breeding, assumed that the first essential was the production of "sports," and to this end he started by intercrossing extreme types, species, or even genera (M'Alpine, *loc. cit.*). Hays, on the other hand, commenced by studying the uniformity of the single plants produced from ordinary commercial Timothy seed, and found that within this material there was such a degree of variation that an attempt to produce new and better strains by selection and breeding within these types was justifiable. Sinclair's contemporaries had gone farther afield, and had selected naturally occurring plants of perennial rye-grass as the foundation of their new strains. Some other workers have endeavoured to cover the whole territory of each species taken in hand, and it has now become a recognized principle, with grasses as with other crop plants, that the first essential in preparation for breeding work is to obtain the most representative population possible of the particular species to be investigated. This position has been arrived at by reason of the fact that in all naturally wind-

GRASSES, THE BREEDING OF HERBAGE (*Continued*)—

pollinated species the variation from plant to plant within the species may be very marked. Further, this variation is not confined to a few characters, but as Witte in particular has shown ("Om formrikedomen hos våra viktigare vallgräs, *Sver. Utsäd. Tids.*, *22*; 20-118, 1912; "Om Timotejen, dess historia, odling och formrikedom samt om föradlingsarbetena med detta vallgräs på Svalöf," *Sver. Utsäd. Tids.*, 25, 1915, reprint), it extends to many morphological and even physiological characters. Moreover, various degrees of difference with regard to any one character may exist, so that as well as the extremes many intermediate types occur. In fact, a population of plants of any one species brought together from all possible sources of origin and planted haphazard presents an almost bewildering diversity of type.

When such plants are grouped and planted according to origin, and particularly according to the type of habitat in which they have been found, the chaos is at once brought to a certain degree of order. Pursuing this line of study, Stapledon ("Cocksfoot Grass [*Dactylis glomerata* L.]: Ecotypes in Relation to the Biotic Factor," *J. Ecol.*, 16; 71-104, 1928) has found it possible in the case of cocksfoot to arrange the types in fairly well-defined groups, and these again show that some definite correlation exists between habitat and the type of cocksfoot plant which flourishes under its particular set of conditions. He has thus succeeded in applying to this species the theory of "ecotypes." This does not mean that within an "ecotype" there is no variation, but that the limits of variation are relatively narrow and well-defined in relation to the extreme differences which exist within the species as a whole.

This principle can probably also be applied to some other species, such as Timothy. It is less applicable in the case of perennial rye-grass, although even here Gregor and Sansome ("Experiments on the Genetics of Wild Populations: I.—Grasses," *J. Genetics*, 17; 349-364, 1927) have found that in some well-defined and relatively stable habitats the type is relatively constant. The present writer has, however, found (T. J. Jenkin, "Perennial Rye-grass at Aberystwyth," *Welsh J. Agric.*, 6: 1930) that plants grown from seed harvested from very old pastures may differ from each other to a marked degree. At the same time, a group of such plants forms a distinct contrast with the groups derived from ordinary commercial seed.

Methods of Breeding—The general methods used in cereal breeding are also applicable to those herbage grass species which are normally self-pollinated, and the same methods in a modified form could also be applied to other species were they found to be normally and fully self-fertile. For the development of methods, it is therefore important to know to what extent, if at all, the most important species are self-fertile.

Körnicke, according to Fruwirth (C. Fruwirth, *loc. cit.*, 1924), found that Timothy, meadow foxtail, cocksfoot, sheep's fescue, meadow fescue, perennial rye-grass, and Italian rye-grass plants, when isolated by

GRASSES, THE BREEDING OF HERBAGE (*Continued*)--

planting very far away from other plants of the same species, produced seed only very sparingly; smooth-stalked meadow grass in a season of good weather conditions gave a fully normal seed yield, but in another season gave very little, while tall oat-grass gave no seed.

Zade ("Neuzeitliche Methoden der Futterpflanzenzüchtung," *Mitt. d. deut. Landw. Gesell.*, 16; 1918) found that isolated plants of cocksfoot and tall oat-grass set seed well when isolated (distance isolation), but this seed in most cases was found to be of very poor germinating capacity.

Distance isolation is impracticable when a large number of plants of the same species have to be tested, and most investigators have been obliged to seek for some method of artificial isolation. The problem has then been found to have two different aspects: (1) whether a single inflorescence, a few inflorescences, many inflorescences, or an entire plant should be enclosed for isolation purposes; and (2) what is the best material that can be used for this purpose. In practice, the first part of the problem has been found to be relatively unimportant, since one method does not, as a rule, give results which are appreciably different from those given by another (see, for example, N. Sylvén, "Själv- och korsbefruktning hos timotej och hundäxing," *Beretning fra N.J.F.s Kongres i Helsingfors*, Juli, 1929).

The second part of the problem is rendered difficult by reason of the fact that presumably the conditions with regard to light and humidity within the enclosed space should be as favourable to pollination, fertilization, and seed development as those outside, while the covering material used should at the same time be absolutely effective in excluding foreign pollen. Frandsen (*loc. cit.*) was not primarily concerned with the covering material used, but he, in turns, employed parchment paper bags, glass cylinders, and linen fabrics. Malte (M. O. Malte, "Breeding Methods with Forage Plants," *Sci. Agric.*, 1921, reprint) states that the method of enclosing a whole plant in cases of cheese cloth or similar material "is commonly employed," but he did not consider this method safe, and so he covered the top and three sides of his cages with canvas, and the fourth (facing away from the prevailing wind) with cheese cloth.

Even denser fabrics than cheese cloth are, however, generally considered to be unreliable, although they are still considerably used. Thus Kirk (L. E. Kirk, *loc. cit.*, 1927*b*) has described a type of cotton sheeting used by him (54 threads to the inch) which he does not consider to be absolutely safe. Carefully selected dense cotton fabrics have also been used to a considerable extent at Aberystwyth for non-genetical work, and experiments now in progress appear to indicate that they are at least highly effective.

Fruwirth (C. Fruwirth, *loc. cit.*, 1913) has tried parchment bags and oiled fabric, while the former method has been chiefly used at Svalöf (Witte, 1919*b*, 1922). The objection to both these is the fact that abnormal conditions are produced. The two have been recently compared in some detail by Knoll ("Untersuchungen über den Einfluss der kunstlichen Isolierung auf die Fruchtbarkeitsverhältnisse bei *Phleum*

GRASSES, THE BREEDING OF HERBAGE (*Continued*)—

pratense, Avena elatior und einigen anderen Grasarten," *Wiss. Arch. Landw.*, A. 2; 318-364, 1929), who found that the conditions within parchment paper cages were distinctly better than those inside the cages made of oiled fabric. He stresses the importance of space in relation to the size of the plant or to the number of inflorescences enclosed, and concludes that the greater the space the more normal the conditions.

The present position is actually as follows: whereas the ideal covering material for out-door work has not yet been found, results so far obtained show, despite the early results of Körnicke, that a wide variation in degree of self-fertility exists between different individual plants of the same species. One plant may produce little or no seed from selfing, while another may be very nearly, if not quite, fully self-fertile. (See, *e.g.*, E. Lindhard, " Planteforaedling ved Tystofte," *Tids. for Landb. Planteavl*, 20; 1913; Frandsen, *loc. cit.*, 1916; H. Witte, " Några undersökninger öfver isoleringens inverkan på timotejens frösättning," *Sver. Utsäd. Tids.*, 32; 87-91, 1922; H. K. Hayes and S. E. Clarke, " Selection in Self-fertilised Lines as a Means of Improving Timothy," *Sci. Agric.*, 5; 313-317, 1924; Fruwirth, *loc. cit.*, 1924; Th. Roemer, " Zielbewusste Regulierung der Bestäubung bei den fremdbefruchtenden Pflanzen," *Mitt. d. l. Gesell.*, p. 443; 1924; Kirk, *loc. cit.*, 1927; Sylvén, *loc. cit.*, 1929; and Knoll, *loc. cit.*, 1929, for further references on isolation methods and results.)

Another important point with regard to methods of breeding follows —namely, what is the effect of self-pollination upon the vigour of the progeny? Lindhard has shown (*loc. cit.*) that in cocksfoot it is possible to retain vigour for at least four generations, but Stapledon (" Selection Work on Herbage Plants," *Rept. Imp. Bot. Conf.*, Cambridge, pp. 73-84, 1925) has found that a certain loss of vigour does occur in this species, although he agrees that at least in the first generation from selfing remarkably vigorous plants occur. In Timothy, figures given by Witte (" Självbefruktungens inverkan på afkommans utveckling hos timotejen [*Phleum pratense* L.]," *Sver. Utsäd. Tids.*, 29; 86-90, 1919*b*) show that selfing, at least in some cases, results in a considerable loss of vigour, but he insists that such loss does not always occur. Hayes and Clarke (*loc. cit.*) dealing with the same species, consider that selfing does not lead to as great a reduction in vigour as has been observed in maize. In their experiments they found that some selfed lines yielded less and others considerably more than the commercial variety. McRostie (" Some Forage Crop Needs and Difficulties in Canada," *Sci. Agric.*, 5; 97-99, 1924), on the other hand, concludes that self-fertilization in Timothy does not seem to be accompanied by any decrease in vigour, and that many strains which are the result of five generations of in-breeding consistently outyield the commercial.

In awnless brome grass Kirk (*loc. cit.*, 1927*b*) reports lower yields from some selfed lines, but argues that this may not be directly attributable to loss of vigour following self-fertilization.

It would seem, therefore, that in these species selfing may or may

GRASSES, THE BREEDING OF HERBAGE (*Continued*)—

not lead to reduction in vigour. On the other hand, the present writer (T. J. Jenkin, "Self and Cross-fertilisation in *Lolium perenne* L.," *J. Genetics*, 17; 11-17, 1926) has shown that in perennial rye-grass there is extreme loss of vigour even in the first generation.

This obviously means that the method of breeding to be adopted depends perhaps to some extent upon the species, but very largely also upon the individual breeding characteristics of the selected plant. The plant which is highly self-fertile and gives vigorous selfed progeny simplifies the problem very considerably. In the first place, by means of its progeny its own breeding properties can be ascertained, since if it is itself highly heterozygous its progeny plants will show wide variation. It then depends upon what degree of variation the breeder is prepared to allow within his new strain whether the plant shall be rejected, or whether by repeated selfing an attempt shall be made to reduce the line to relative homozygosity. If, on the other hand, the progeny plants are reasonably similar, strain building may proceed at once, using the selected plant and its progeny for this purpose. In fact, much of the breeding work done at Svalöf appears to have been conducted on this basis (H. Witte, "Årsredogörelse för förädlingsarbetena med vallväxter under 1910," *Sver. Utsäd. Tids.*, 21; 247-256, 1911). A number of single plants are selected, first individually, then in clone beds. The best clone beds are selected and are further increased vegetatively, so that relatively large areas, each consisting of the propagants of a single selected plant, are made for seed production in isolated positions. Seed so obtained is used both for the study of uniformity of type (single plants) and for field trials, and on the results of these studies and trials the final selection is made.

The uniformity of the strain produced by this method will depend upon the degree of homozygosity of the foundation plant. For practical purposes, it is not essential that a foundation plant should be homozygous in the strict genetical sense, but, as explained by Stapledon (*loc. cit.*, 1925), all that is necessary is that it should breed true to a general but well-defined type.

Where the selected plant is highly self-sterile its breeding properties cannot readily be studied by means of its selfed progeny, but an excellent plant cannot easily be rejected on this score alone. A more elaborate method of breeding may then be necessary. Such a plant may be intercrossed with several others which appear to be of approximately the same type, intercrossing being done in all possible directions (diallel crossing). A simple case would be A×B, B×C, C×A. In this way the breeding properties of each plant can be studied to some extent, and it can also be ascertained whether the progeny families obtained are sufficiently uniform to form the basis of a new line. This method is not very different from those suggested by Zade (*loc. cit.*, 1918) and by Stapledon (*loc. cit.*, 1925). It is also applicable to those cases where there is serious loss of vigour from selfing.

Methods suggested by other breeders, such as Hays (quoted by Fruwirth, 1913), Fruwirth (1913, 1924), and others, differ from the

GRASSES, THE BREEDING OF HERBAGE (*Continued*)—

above in certain details. For example, it may not be possible to proceed immediately from the single plant originally selected to the building up of a new strain. Reselection may be necessary after the first generation or in several generations in order that the strain type may become "fixed." Whether this can be done depends largely upon the method of reselection employed. If types similar to the original plant, which itself has proved unsatisfactory owing to variation amongst its progeny, are continuously selected, the danger is that selection for heterozygosity is unconsciously made at the same time.

The simplest and most rapid method of all—namely, mass selection—ignores many essential points. In this case, morphologically similar, or approximately similar plants are grouped irrespective of their own breeding properties. They are allowed to interbreed, and reselection on the same basis is made in the next, and in succeeding generations. Even this form of breeding may easily lead to the production of a strain which is definitely superior to the ordinary commercial type.

Intercrossing—Reference has already been made to certain instances where it may become necessary to intercross two plants. This has sometimes been carried out by simply enclosing two plants or the inflorescences of two plants together for mutual pollination (A. Zade, "Aufgaben der deutschen Futterpflanzenzüchtung," *Landw. Jahrb. für Bayern*, No. 8/9, 1929). In other cases (Sylvén, 1929) pollen is brought from the male parent and dusted over the unemasculated inflorescences of the female parent. These methods are relatively easy, and in most cases the seed obtained is probably mostly the result of intercrossing. There is always the uncertainty, however, unless the female parent is absolutely self-sterile, that an unknown proportion of the seed is the result of selfing. This proportion will probably vary from one family to another, and therefore a direct comparison of families so produced is impossible.

Garton, according to M'Alpine (*loc. cit.*), used a method similar to that used in cereals, and in some cases he appears to have been fairly successful. Fruwirth (1924) advocates the use of an essentially similar method, although Oliver ("New Methods in Plant Breeding," *U.S. Dept. Agric. Bureau of Plant Industry, Bul.* 167, 1-39, 1910) had introduced the "washing" method of depollination. This latter method has, however, not been widely adopted, and according to von Tschermak (In Discussion on Fruwirth [1913], *Beiträge zur Pflanzenzucht*, p. 133, 1913) seldom leads to results.

By adopting still another method the present writer (T. J. Jenkin, "The Artificial Hybridisation of Grasses," *Welsh Plant Breeding Station, Aberystwyth, Bul. Series H., No.* 2, 1924) has successfully made intra-specific crosses in such species as the rye-grasses, the fescues, cocksfoot, tall oat-grass, Timothy, and meadow foxtail, as well as certain interspecific and intergeneric crosses. This method has been considerably used in the genetical study of perennial rye-grass (T. J. Jenkin, "Inheritance in *Lolium perenne* L. I.—Seedling Characters,

GRASSES, THE BREEDING OF HERBAGE (*Continued*)—

Lethal and Yellow-tipped Albinos," *J. Genetics*, 19; 391-402, 1928*a*; "Inheritance in *Lolium perenne* L. II.—A Second Pair of Lethal Factors," *J. Genetics*, 19; 403-417, 1928*b*).

The Genetics of Herbage Grasses—Very little purely genetical work has as yet been done on the herbage grasses. Witte (*loc. cit.*, 1919*a*) has formed the opinion that in Timothy several morphological characters are inherited. He has also found evidence (1919*b*) that in the same species high and low self-fertility are inherited characters. Hayes and Clarke (*loc. cit.*) have also found a high correlation coefficient for seed setting in parents and progeny in the same species, while Kirk (*loc. cit.*) has obtained somewhat similar results with awnless brome. Stapledon (*loc. cit.*) also reports a considerable degree of segregation for this character in cocksfoot.

In Timothy, Witte "Über weibliche Sterilität beim Timotheigras (*Phleum pratense* L.)," *Svensk Bot. Tids.*, 13; 32-42, 1919 has studied the inheritance of female sterility, and although he failed to obtain results by artificial hybridization, he concluded that this character is recessive to female fertility. Kajanus ("Zur Genetik des Chlorophylls von *Festuca elatior* L.," *Bot. Notiser*, p. 131, 1921, reprint) by the method of self-pollination has found that albinism in *Festuca elatior* is recessive to full green, while the present writer, depending chiefly upon hand-crossing, has investigated a case of chlorophyll deficiency and two cases of lethal effect in perennial rye-grass (Jenkin, *loc. cit.*, 1928).

T. J. J.

GRASS SEED, PRODUCTION OF—In Northern Ireland during the four years 1925-28, grass seed was saved over an average annual area of 95,853 acres, representing about 45 per cent. of the area devoted annually to first and second years' hay. In districts where the saving of grass seed is extensively practised, the hay crop is of equal importance with the cereal crops in the general economy of the farm. According to the "Agricultural Output of Northern Ireland, 1925," *Min. Agric. N. I.*, the value of grass seed sold off the farms in that year was £540,000. After potatoes and flax, this crop is, thus, the most important one grown for sale off the holdings, and ranks as one of the principal money crops in Northern Ireland.

Origin and History of the Industry—A firmly established industry such as this may safely be presumed to be of long standing, but actually the tracing of its origin and history is a matter of difficulty. Even in the *Journal of the Department of Agriculture and Technical Instruction for Ireland*, the earliest reference to the crop occurs as a brief and anonymous article in vol. ix., No. 3, 1909.

Mercer (*Agric. Prog.*, vol. vi., 1929) points out that perennial rye-grass was the first of all permanent grasses to be grown pure for forage, and refers its earliest mention in English literature, as also its first cultivation in Oxfordshire, to the early seventeenth century. He derives the name ray-grass or rye-grass from the mediæval French "ivraye." The value of perennial rye-grass was fully realized in certain

GRASS SEED, PRODUCTION OF (*Continued*)—

districts of England in the early eighteenth century, as witness Lisle ("Observations on Husbandry," Edward Lisle, Esq., 2nd edit., 1757), who cites a case in Dorset where seed to the value of £20 was saved from 18 acres. The seed was sold for 1s. 10d. and 2s. 0d. per bushel, and sown at the rate of 3 bushels per acre.

Some two centuries after the recognition of the merits of the type now known as perennial, a distinct, short-lived and heavy-cropping form of rye-grass was developed in Lombardy, and came to be distinguished as Italian rye-grass. The precise relationship between the two types is still a moot point. According to Mercer it was in Scotland that Italian rye-grass was first used in British husbandry. In the course of time rye-grass seed production became a recognized industry in Ayrshire.

Mercer traces the beginnings of grass-seed sowing in Ireland to the activities of certain Scottish immigrants from Ayrshire, who settled around Banbridge, about a century ago, and transplanted an industry already thriving in their native district. Following closely upon the establishment of the new industry, there arose firms who undertook the handling of the seed, and the co-operation of all concerned gradually created and consolidated a trade in which Northern Ireland now ranks as chief world-centre.

Development of the Industry—A similar paucity of data precludes any attempt at a detailed survey of the development of the industry. The scope of the agricultural statistics collected has only recently been extended to include this crop. In the *Journal of the Department of Agriculture and Technical Instruction for Ireland,*" vol. ix., 530, 1909, the area from which grass seed was saved in 1908 is estimated at 75,000 acres. This area was divided among the following eight Ulster counties in order of extent, viz., Down, Armagh, Londonderry, Monaghan, Tyrone, Antrim, Cavan, and Donegal. Apparently, no seed was saved in Fermanagh.

That a very large increase in the extent of the practice has developed since that time is evident from the following table, the acreages and output returns in which refer to areas under the Government of Northern Ireland only, thus excluding Monaghan and Cavan.

Year.	*Hay Saved for Seed (Acres.)*	*Estimated Value of Grass Seed Sold off Farms.*
1924	104,866	—
1925	104,170	£540,000
1926	95,114	560,000
1927	93,518	520,000
1928	91,108	380,000

A small but continuous decrease in the area saved is evident; its effect on output quantities and values is, of course, complicated by varying yields and prices.

Species and Varieties Concerned—The relative importance of the various grasses saved may be gauged from the following table of

GRASS SEED, PRODUCTION OF (*Continued*)—

acreages, which also shows the percentages of the total area in each year represented by the acreages quoted.

Species.	1924. *Acres.*	1924. *Percentage of Total Acreage.*	1928. *Acres.*	1928. *Percentage of Total Acreage.*
Perennial rye-grass	70,536	67·26	68,707	75·40
Italian rye-grass ..	16,326	15·57	11,507	12·64
Mixed perennial and Italian	17,139	16·34	10,133	11·12
Crested dogstail ..	865	0·83	761	0·84

The practice of saving mixed perennial and Italian rye-grass seed has been discouraged in recent years by the purchasing and seed-cleaning firms, who prefer to handle pure stocks. As a consequence the proportion of perennial rye-grass saved has been steadily on the increase since 1924, principally at the expense of the area devoted to the "mixed seed." Despite minor fluctuations, the areas under Italian rye-grass and crested dogstail have remained fairly constant in recent years.

Distribution of the Varieties—The table which follows shows the distribution of the 1928 crop by counties:

County.	*Perennial Rye-grass.* Acres.	*Italian Rye-grass* Acres.	*Mixed Perennial and Italian.* Acres.	*Crested Dogstail.* Acres.
Antrim	7,024	2,069	2,532	84
Armagh	13,379	2,298	551	8
Down	29,105	2,389	1,525	594
Fermanagh ..	145	16	31	—
Londonderry ..	10,891	1,561	4,739	39
Tyrone	8,163	3,174	755	36

It will be observed that Fermanagh made the smallest contribution to the total acreage. County Down, on the other hand, was responsible for no less than 42·4 per cent. of the whole 1928 crop of perennial rye-grass, and County Tyrone had the largest area under Italian rye-grass, while about half of the crop of mixed seed came from County Londonderry. Perennial seed is saved over a very wide area, but the principal rural districts concerned are Banbridge, Downpatrick, Newry, Armagh, and Magherafelt. Italian has not nearly so wide a distribution; the vast bulk of the crop comes from the rural districts of Magherafelt, Cookstown, Armagh, Lurgan, Moira, and Lisburn, areas bounding Lough Neagh to the south and west. "Mixed seed" is mainly produced in northern districts such as Londonderry, Limavady, Coleraine, and Ballymena.

The saving of crested dogstail is a very strictly localized industry centring in Hillsborough, and occupying a small area to the south-east of Lough Neagh.

GRASS SEED, PRODUCTION OF (*Continued*)—

Influence of Soil and Climatic Conditions in determining Distribution of Varieties—The distribution of the varieties thus outlined may be assumed to be governed by the results of long experience. Of the two rye-grasses, Italian, as the heavier cropper, and usually commanding the higher price, is grown wherever possible. But Italian is much more exacting in its requirements than perennial, and requires a rich, deep, loamy soil for really successful cultivation. Perennial is much more adaptable, and thrives on almost all types of soil, but is eminently suited to the best class of limestone soil. Though it so happens that Italian is mainly grown in the driest area of Northern Ireland, within a rainfall range of 30-39 ins., and that perennial is practically excluded from the area of rainfall 30-36 ins., it would be unsafe to attempt to establish a relation between these facts on the insufficient date available at present.

The practice of mixing the two grasses originates in an effort to secure maximum yields in intermediate conditions, and the amount of Italian entering the mixture is governed by the suitability of the conditions for that variety.

Crested dogstail requires a heavy, moist, deep soil.

Source of Seed—The perennial seed used is usually either of local origin or is obtained from Scotland (Ayrshire), although experiments indicate that the best local seed is equal to, or better than, the Scotch seed. The bulk of Scotch seed entering Northern Ireland is imported in a "rough" state to be cleaned and graded before sale. The Italian rye-grass seed sown is usually of local origin, but a small proportion of French-grown seed is also used. Crested dogstail supplies are almost entirely drawn from seed of local origin. In 1927 and 1928, respectively, 26,250 and 20,262 cwts of grass seed were thus imported. The seed is generally sold to the farmers by local agents of the cleaning firms, and as the produce is in many cases purchased by the same agency, the quality of the seed supplied concerns all interests to an equal extent.

Place of Crop in Farm Rotation—The crop of perennial rye-grass for seed always follows the last oat crop of the rotation, the grass seeds being sown in conjunction with the oats. Italian rye-grass intended for seed was formerly treated similarly, but the practice has altered in recent years and it now follows the lea oats, taking the place of flax in the rotation, thus: Lea oats with grass seeds—Italian rye-grass—green crop—oats with grass seeds—perennial rye-grass. Italian rye-grass and flax are rarely cultivated in the same districts. Where flax is grown, perennial rye-grass occurs in the rotation in either of two places —viz., lea oats—flax—green crop—oats—perennial rye-grass—the usual practice; or, lea oats—green crop—oats—flax with grass seeds—perennial rye-grass. Mixed seed and crested dogstail are treated similarly to perennial rye-grass in the rotation.

Characteristics and Price of Seed—The basic seed price is subject to the usual fluctuations regulated by demand and supply, but apart

GRASS SEED, PRODUCTION OF (*Continued*)—

from these the price varies also according to the bushel weight and purity of the sample. Average prices in 1928 were as follows:

Perennial Rye-grass.		*Italian Rye-grass.*	
Per bushel of 28 lbs. ..	9s. 9d.	Per bushel of 22 lbs. ..	9s. 1d.
,, ,, 26 ..	8d. 10d.	,, ,, 20 ,, ..	8s. 6d.

From 1922 to 1928 perennial rye-grass average prices per 28 lbs. bushel varied from 13s. 4d. to 8s. 11d., while Italian rye-grass average prices per 22 lb. bushel ranged from 11s. 4d. to 7s. 1d.

Crested dogstail is usually sold at 1s. 6d. to 2s. 0d. per lb.

Good seed samples have a bright silver colour and are odourless. They should be free from brome (*Bromus mollis*), Yorkshire fog (*Holcus lanatus*), and hairgrass (*Festuca sciuroides*) seeds. Samples of all seeds can be obtained with a purity of 98 per cent., but the germination of perennial averages about 87 per cent., Italian 84 per cent., mixed 83 per cent., and crested dogstail about 80 per cent.

Time, Rate, and Method of Sowing—When rye-grasses are to be sown in conjunction with either oats or flax, the land is prepared in the ordinary way for these crops, which are then sown and covered. With oats, rye-grass seed is sown either within a few days of the oats or three to four weeks later, when the young oat plants are well established. The latter procedure is usual on very rich soils where the grasses, if sown sooner, would become too luxuriant and render harvesting difficult, especially in wet seasons. With oats the time of grass-seed sowing thus varies from mid-March to early May. When flax is the chosen nurse crop the grasses are sown on the same day, or as soon after as circumstances permit, and the sowing period ranges from mid-April to mid-May.

One to one-and-half bushels per acre of perennial rye-grass is the usual amount sown, to which is added 8 lbs. of cocksfoot, 3 lbs. of Timothy, and 1 lb. of wild white clover seed. The mixture varies from district to district. On heavy soil the proportion of Timothy is increased and rough-stalked meadow-grass and meadow fescue are included. Italian and mixed rye-grass seed are sown at equivalent rates, 35-40 lbs., but Italian is sown alone and not as a component of a mixture of seeds. The proportion of Italian in mixed seed varies from one-third to two-thirds according to the adjudged Italian-growing capacity of the soil. Mixed seed, like perennial, is intended for grazing, and similar quantities of the other grasses and of wild white clover are added before sowing. Crested dogstail is sown at the rate of 20 lbs. per acre and is sown unmixed with any other grasses or clovers.

Before sowing the grass seeds, the field is harrowed and rolled, the rolling being intended to create a firm bed for the smaller seeds of the mixture rather than for the rye-grass. The seed is broadcast, usually by means of a "fiddle," a handy instrument in which the bowing action of the sower rotates a metal disc on to which the seed is fed, thus scattering it by centrifugal force to about 4 yds. on each

GRASS SEED, PRODUCTION OF (*Continued*)—

side of the sower. After sowing, a light harrow is used for covering, and a second rolling is generally advisable.

Cultivation and Manuring—The grasses benefit from such manures as are applied to the crop with which they are sown. Oats occasionally receive either a complete manurial dressing or a light application of nitrate of soda or sulphate of ammonia. Flax is usually given a dressing of muriate of potash at the rate of 1½ cwts. per acre. It is usual, however, to apply a dressing of sulphate of ammonia at the rate of 1 cwt. per acre, often in conjunction with 3 cwts. of superphosphate, to the grass in the spring following its sowing. It is doubtful if any benefit accrues from the addition of the superphosphate, which tends rather to encourage immature ripening with a consequent decrease in yield and bushel weight of the seed, and diminution of the hay yield. Crested dogstail usually receives 1 cwt. of sulphate of ammonia per acre each year, and in its second year a dressing of farmyard manure also.

Sheep are often run over the fields in spring to encourage stooling and thickening. The practice is not universal, but is largely governed by the scarcity of other food at the time, and there is a danger that in light soils it may defeat its object by the consequent removal of such plants as are not well rooted.

Harvesting—Perennial rye-grass is likely to give a maximum yield of seed if cut at that stage of ripening when the three lowest spikelets are ready to drop off, usually about three weeks after the crop would have been ordinarily cut as hay, and from the last week of July to the first week of August. Italian rye-grass ripens a fortnight later, crested dogstail a week earlier than perennial rye-grass.

A reaper is usually employed for harvesting, as the self-binder is apt to occasion too great a loss of seed. The crop is tied in sheaves and stooked immediately to minimize loss of seed by shattering. The sheaves are arranged either in half-stooks of three a side or, more commonly, in fours, and tied at the top with bands. When sufficiently dry, usually after two to three weeks of fine weather, the stooks are assembled in small clamps or handstacks of 100-150 sheaves. Ordinarily two weeks at least elapse before the earliest threshing, which is always done out of the clamps to prevent seed losses by further handling. If the crop has to be conveyed to the thresher, this is done by ricklifters, and where none is available threshing is usually done in the field.

Threshing and Preliminary Cleaning of the Seed—The threshing methods in use range from the very primitive to the most up-to-date. Sometimes the seed is collected on a sheet in the field, the sheaves being dashed against the edge of a plank or ladder fixed horizontally over the sheet. Occasionally the flail is still employed, and it is claimed to cause fewer broken awns in Italian rye-grass than the power thresher. Barn threshers, horse and power driven, are used, but seed so threshed usually needs subsequent riddling, winnowing, and sieving—unnecessary operations when the travelling power thresher

GRASS SEED, PRODUCTION OF (*Continued*)—

has been employed. The degree of seed purity attained by the farmer depends on the machinery available, but Yorkshire fog (*Holcus lanatus*) and pieces of hay, at least, should be removed before the seed leaves the farm. Hair-grass (*Festuca sciuroides*) and soft brome (*Bromus mollis*) cannot be satisfactorily removed by the appliances at the farmer's disposal.

After cleaning the seed is usually spread out in a thin layer on a loft floor to dry and improve in condition before sale.

Yield per Acre and Total Production—The yield of seed varies with both season and district. Perennial averages about 5·5 cwts. per acre, and may give as much as 8 cwts.; Italian averages about 6 cwts. per acre, and may give 9 cwts.; mixed seed yields are usually less variable, and average about 5 cwts. per acre; while crested dogstail averages about 4·5 cwts. per acre.

The total production, in hundredweights, for the two years 1927 and 1928 was as follows:

Year.	*Perennial Rye-grass.*	*Italian Rye-grass.*	*Mixed Perennial and Italian Rye-grass.*	*Crested Dogstail.*
	Cwts.	Cwts.	Cwts.	Cwts.
1927	372,400	74,082	71,901	2760
1928	408,438	71,286	53,670	3551

Threshed hay is worth £1 to £2 per ton less than the unthreshed hay, and the hay yield is about 20 per cent. lower when grass seed is saved.

Disposal of the Seed—The threshed seed is usually put up in 1½ cwt. sacks and taken to recognized markets. The buyers, almost entirely agents of seed cleaning and exporting firms, sample the seed, testing its condition and purity. The presence of hair-grass and soft brome, in quantity, detract from the value of the sample to the extent of 1s. or 2s. per cwt. Sale by sample depends on the good faith of the seller, but is increasing. The bulk of the seed is sold in September, October, and November, though markets are held until February. The following table shows the average prices per hundredweight obtained in various seasons:

Year.	*Perennial Rye-grass.*	*Italian Rye-grass.*	*"Mixed" Rye-grasses.*
	s. d.	s. d.	s. d.
1909	15 0 to 16s.	16 0	....
1911-13	15 1	11 6	11 6
1925-26	19 2	16 7	14 5
1926-27	28 2	17 0	17 2
1927-28	21 4	23 7	17 11
1928-29	13 8	18 9	12 10

Perennial has in recent years been outpriced by Italian, and the relative value of mixed seed has decreased very rapidly. Crested dogstail usually reaches about 80s. per cwt., and is mainly sold on sample.

Cleaning by Wholesalers—The seed after purchase is graded into three classes by the machiners: (1) clean and heavy; (2) clean and light; (3) inferior. Corresponding grades from all sources are care-

GRASS SEED, PRODUCTION OF (*Continued*)—
fully mixed before cleaning. The machines used in cleaning are the "rea," which extracts very coarse and very fine impurities such as straw, "goose-grass" (*Bromus mollis*), hair-grass, and sand; the "jigger," which takes out goose-grass and buttercup (*Ranunculus repens*) mainly; and the indented cylinder, which removes small perennial, heavy holcus, small buttercup, and rib-grass (*Plantago lanceolata*). An aspirator is then used to give a sample the desired weight. After cleaning a sample is sent to an approved seed testing station for analysis.

The regulations of the Seeds Act, 1920, only apply to Northern Ireland in setting a limit (5 per cent.) to the proportion of injurious weed seeds in any sample of seeds exposed for sale. There is no compulsion upon a merchant in Northern Ireland to furnish particulars of purity and germination with any sample sold, though this is often done voluntarily. Seed exported to Great Britain and other countries, however, must conform to the standards imposed by the regulations of the importing country, and must be accompanied by a statement of the bushel weight, percentages of purity and germination, and percentage of injurious weed seeds, if this is in excess of 2 per cent. In the case of rye-grasses, if the percentage of purity is not less than 98 per cent., and the percentages of germination not less than 80 per cent. in the case of Italian, 85 per cent. in the case of perennial, and 82 per cent. in the case of "mixed" seed, a statement to that effect is sufficient. (See Seed Control.)

"Mixed" seed as a rule has a lower germination than pure samples of either of its constituents. This is probably due to the difference in time of ripening between the two grasses, which necessitates cutting when a proportion of the perennial is already over-ripe and a proportion of the Italian definitely under-ripe.

Mercer estimates the moisture content of the cleaned and aired seed in a good season at about 13 per cent., but points out that ripe rye-grass can gain and lose 7 or 8 per cent. of its weight by absorption and exhalation of moisture in a few days. The moisture content is ultimately connected with the shipment difficulties often experienced, and a low moisture content is preferred by shippers.

The loss of bulk during cleaning depends on the impurities present, but must average from 15 to 20 per cent. The impurities are kept separate in bulk, and after all the grass seed has been cleaned are then graded by machinery into: (1) goose-grass, (2) hair-grass, (3) Yorkshire fog, and (4) other weed seeds, dock, clover, etc. The Yorkshire fog is usually sold in Germany, and hair-grass, when cleaned, also finds a ready market on the Continent.

In the disposal of these by-products the degree of germination appears to be of little importance as seed several years old finds as ready a sale as fresh seed. "Goose-grass," when pure, is readily disposed of in southern France and other parts of the Continent. The other impurities are marketed in centres like Belfast, where they are used for mixing with chaff for stock feeding; this residue of impurity realizes from 2s. to 3s. per hundredweight.

GRASS SEED, PRODUCTION OF (*Continued*)—

Exports of Grass Seed—The following table shows the quantity and value of the exports of grass seed from Northern Ireland ports from 1922 to 1928, but these totals doubtless include seed grown outside Northern Ireland, particularly from the counties of Monaghan and Cavan.

Year.	*Quantity (Cwts.)*	*Value.*
1922	359,747	£517,713
1923	357,558	534,240
1924	269,247	409,066
1925	344,197	467,718
1926	267,412	385,362
1927	259,550	
1928	295,762	

Experimental Work on the Crop—While a certain amount of experimental work has been carried out on the hay crop, very little has yet been done to improve the type of plants in general use. The lines of inquiry that are being followed bear on the source of seed, the time of cutting, and the effect of manuring. The formation of pure strains of grasses is, owing to their natural cross-fertilization, a matter of supreme difficulty. Bearing in mind the ready cross-fertilization possible between perennial and Italian, a crop of mixed grass might be expected to show all grades of intermediacy. Actually, the two types remain remarkably distinct, as though from the mixed pollen available each preferred fertilization by pollen of plants of its own type. More light on this question of selective pollination in the rye-grasses has been given by Gregor (*Trans. R.S.E.*, vol. xliv., part iii., No. 30, 1928; see also Grasses, Breeding of Herbage). I. W. S.

GREEN GAGE—See Stone Fruits, under Fruit.

GREEN MANURING—Green manuring, as distinct from catch cropping, is the ploughing under of any green crop like mustard or tares as a cheap and convenient method of adding to the fertility of a soil. It is an alternative to an application of farmyard manure, and is particularly valuable for maintaining fertility in fields which are not readily accessible to the dung cart. The practice has been widely adopted throughout the world, but it was more popular in Britain some years ago than it is to-day.

Love, writing in 1868, suggests, as reasons for the decline in green manuring, the introduction of guanos and increased meat prices, which made it more profitable to eat green crops on the land rather than plough them in (*J.R.A.S.E.*, vol. iv., ser. ii.).

Though the possibilities of green manuring have never been fully exploited, and deserve more extensive trial, there are many conditions which militate against the practice becoming a standardized means of enriching soils in this country; limitations of climate, of cropping, and of farm practice all tend to lessen the value of green manuring and prevent its wider adoption. In certain areas, however, particularly early potato growing districts, green manuring is appreciated properly, and widely practised.

GREEN MANURING (*Continued*)—

The purpose or objects of green manuring may be considered broadly under three heads:

(1) Physical or Mechanical.
(2) Chemical.
(3) Biological.

(1) *Physical or Mechanical.*—When a green crop is ploughed under, an addition is made to the store of humus which improves the texture of heavy soils and increases the water-holding properties of light soils. Heavy soils are, therefore, made easier to cultivate, drainage is facilitated, and the temperature of the soil is raised. Light soils are rendered more retentive, and with the increase in organic content are more reliable for cropping.

On soils which are unsuitable for roots, weeds can be checked by green manuring. On such soils as many as three heavy crops of mustard in succession may be ploughed under during the course of the summer; such a growth eradicates weeds in addition to enriching the soil.

(2) *Chemical.*—During the winter months and periods of heavy rainfall, there is a serious loss of nitrates on uncropped land through leaching. Rye or mustard, or some other suitable catch crop, sown after early potatoes have been lifted or after the harvesting of a corn crop, will prevent much of this loss. The nitrates will be taken up by these green crops and converted into proteins which, as the plant materials decay, will become available to subsequent crops. Growing crops focus nitrogen obtained from the soil, subsoil, and atmosphere and restore it to the land when ploughed in.

Green manuring does not increase the amount of phosphoric acid or potash in the soil, but returns these minerals only in the same amount as they were taken up. The amount of nitrogen in the soil, however, is increased, particularly where a leguminous plant is used. There is also some evidence that potash is rendered more available by green manuring.

(3) *Biological.*—An increase in the store of humus in the soil means an increase of food for the nitrifying bacteria and other forms of life necessary to the maintenance of fertility. As a means of improving conditions for the life of these organisms by aeration in heavy soils, and by increasing the store of food materials in light soils, green manuring is of particular value.

Apart, morever, from this aspect of bacterial life, green manuring offers a practical means of preventing damage to crops by insect and other pests. In many heavy land districts where it is customary to sow wheat in the autumn after a bare fallow, an attack of Wheat Bulb Fly (*Hylemyia coarctata*) is experienced frequently in the following March and April. The Wheat Bulb Fly lays its eggs on bare ground in July. If a crop like mustard is sown on the land about the middle or end of June, instead of leaving it lying uncovered, the chances of an attack from this pest are greatly reduced.

There is, too, a widely held belief that mustard will kill Wireworms. There is no evidence to support this, but general experience shows that

GREEN MANURING (*Continued*)—

a crop of mustard ploughed in where Wireworms have been troublesome will usually lessen attacks on subsequent crops. Green manuring has been found also to give control of two potato diseases, Common Scab (*Actinomyces scabies*) (Comber, "Scientific Study of the Soil," Arnold) and sprain or Internal Rust Spot (*Bacterium rubefaciens*) (Jowett and Lowry, *Bull. No.* 160, *University of Leeds*).

The method adopted is to sow rye as soon as possible after the removal of the corn crop, and to stimulate growth of the crop by applying 1 cwt. of nitrate of soda per acre. The green crop is then ploughed under during the following March or April. The greater the bulk of green crop ploughed under, the better is the control obtained.

Types of Green Manuring—A green manuring crop, generally speaking, should not take the place of a main crop, though there are exceptions which will be mentioned later, and it should not interfere with the cultivations for or the growing of the next main crop. The result of these limitations in practice has been the evolution of three main types of green manuring:

(1) *Summer-Sown Catch Crops.*
(2) *Autumn-Sown Catch Crops.*
(3) *Under-Sown Catch Crops.*

Page describes a series of experiments, begun in 1924 under the Research Scheme of the Royal Agricultural Society, in which various crops under the three headings given above were tested for their suitability as green manures. The results were, however, rather indefinite, and brought out no striking differences (Rothamsted Conferences, "Green Manuring Scheme," Benn, London).

(1) *Summer-Sown Catch Crops*—The greatest amount of green manuring in this country, particularly in districts of low rainfall, is done by crops sown in summer. The practice and the crop used vary with the district. For example, on heavy land which has been bare or "summer" fallowed, mustard may be sown in July and ploughed under for wheat in October. Mustard may be sown earlier and ploughed under when 4 to 6 ins. high, and another crop sown which will be ploughed under before sowing the land with wheat. With a chain fitted to the plough, very large quantities of green herbage can be buried completely. On light land where early potatoes have been harvested the same practice may be adopted, although lupins may be used instead of mustard. (See Lupins.) The latter, however, almost invariably gives the better results under all circumstances.

In the early potato growing districts of Ayrshire, Italian ryegrass, barley, and rape are the common catch crops, but these more often are used for late autumn "keep" for lambs than for green manuring.

On the chalk lands where tares have been eaten off with sheep, cole seed may sometimes be sown instead of mustard and ploughed under, though, again, this crop is more generally used for folding.

Summer-sown catch crops are intended as green manures for autumn crops like wheat and winter oats.

GREEN MANURING (*Continued*)—

(2) *Autumn-Sown Catch Crops*—Even in the earliest districts corn harvest is not usually completed until the end of August. The sowing of crops, after corn, for green manuring cannot, therefore, take place before September, and such crops will only be of benefit as manure for main crops to be sown or planted in the following spring, for no green crop could make sufficient bulk in the short time available to benefit any autumn- or winter-sown corn crop. Mustard may again be used for this purpose, but it must be ploughed under by November as it is subject to frost damage. More suitable crops are winter tares, rye, trifolium, and rye-grass. These are ploughed under in spring and are followed most frequently by potatoes or some other root crop. Green manuring is rarely used as a preparation for spring oats or barley, and it is not a practice to be recommended. Autumn-sown catch crops are practicable only in areas of moderately high rainfall, and where the winter is not unduly severe. The practice is not suitable for the eastern counties of England, as the green crop uses up so much of the winter moisture that there is not sufficient left for the satisfactory growth of the subsequent root crop. This type of green manuring is fairly extensively practised in the south-western counties and in parts of Surrey and Sussex.

(3) *Under-Sown Catch Crops*—This method of green manuring is similar to the ordinary practice of sowing clover and grass seeds under corn in spring. It is not a method practised extensively, and, indeed, is localized to certain districts in Scotland, notably the Lothians and Fifeshire, and to south-west England. It is, to some little extent, attempted in other areas, but, particularly in dry seasons, the danger of the seeds failing is so great that it is not widely adopted. The crops more commonly used for under sowing are trefoil, alsike, Italian rye-grass, and red clover. These may be ploughed under for either autumn- or spring-sown main crops. Under this heading a practice which is gaining favour in south Lincolnshire may be considered, though it is a case of using a main crop instead of a catch crop for green manuring. The rotation largely followed in that area is wheat, clover, potatoes. The red clover is cut in June and left lying on the ground; the second crop comes up through it and the whole lot is ploughed under during the winter. In all main crop potato growing districts it is customary to plough under the second crop of red clover as manure for the potatoes, farmyard manure usually being applied before the clover is ploughed in. There is no better preparation for potatoes, and red clover has truly been described as the "King of Green Manuring Crops." (See Potato.)

Finally, there is the "long ley" type of green manuring practised throughout Scotland and northern England. Grass and clover seeds are sown in the rotation and left down for at least three years. The grass is freed of stock early in the last season, so that as great a growth of herbage as possible may be obtained for ploughing under. This is perhaps an extreme case of green manuring, and another example of using a main crop in place of a catch crop. The fertility which is added to the soils, particularly since the introduction of wild white

GREEN MANURING (*Continued*)—

clover in the mixtures of grass and clover seeds, by these long leys is, literally, enormous.

It is not unusual, before ploughing under any crop for green manuring, to apply a dressing of freshly made farmyard manure. In practice this has been found to give much better results than the green manure alone. The difference is not wholly accounted for by the small amount of farmyard manure applied. Farmer Giles suggests that dung applied to a green manure crop may act in much the same way as a starter put into cream for butter making. The explanation is certainly novel, and it may be worth consideration ("Manures and Manuring," Farmer Giles, Pearson). (See Nitrification.)

Green manuring intelligently practised is worthy of much wider application, and an extension of the practice is bound to come with the ever-increasing cost of dung making and carting. Even in spite of the many limitations which lessen its use as a substitute for farmyard manure, there is no system of arable farming which does not lend itself to a considerable extension of green manuring as a cheap and convenient method of suppressing weeds, conserving nitrogen, and, in general, of accumulating fertility in soils, which is the true basis of good farming.

Unfortunately there is little experimental data in green manuring available for the farmer, and experiments in the past have shown what to avoid rather than new and better lines to follow.

Bibliography.—Rothamsted Conferences, III., "Green Manuring," Benn; Wrightson and Newsham, "Agriculture, Theory and Practice," Crosby, Lockwood and Son; Macdonald, "Stephen's Book of the Farm," Blackwood and Sons; Hawk, "Agricultural Experiments in Cornwall," Netherton and Worth; Hopkins, "Soil Fertility and Permanent Agriculture," Ginn; Fletcher, "Soils," Constable; Farmer Giles, "Manures and Manuring," Pearson; "British Husbandry," vol. i., Baldwin and Cradock; Wilkins, "Research and the Land," H.M. Stationery Office; *J.R.A.S.E.*, vols. 85 and 87; *J.R.A.S.E.*, vol. iv., ser. ii., 1868; Hall, "Fertilizers and Manures," Murray; Comber, "Scientific Study of the Soil," Arnold.

J. C. L.

GREY SPOT (**of oats**)—See Diseases of Cereals, under Wheat.

GROATS—For composition and value when fed to poultry, see Poultry, Nutrition.

GROUND GAME ACT, 1880—See Improvements and other Rights, Compensation for.

GROUND NUT—For composition and feeding value, see Feeding Stuffs.

GROUND-NUT CAKE—For composition, feeding, and manurial values, see Feeding Stuffs.

GUANO—See Fertilizers.

GUINEA FOWL—See Poultry.

GYPSUM ($CaSO_4,2H_2O$)—A naturally occurring sulphate of calcium crystallizing in the monosymmetric and orthorhombic system, with a transition temperature as in the case of sulphur. Its use directly as a manure is chiefly in the amelioration of alkaline soils, as in India and the United States. In this country a certain amount is incidentally applied in the use of superphosphate (*q.v.*). (See also Calcium.)

HARDENING (of plants)—See Winter Hardiness and Drought Resistance.

HEADLANDS—The headlands (sometimes endrigs or headrigs) form that portion of a field at the end of the furrows required to give room for the turning round of horses or mechanical implements when ploughing or cultivating. Headlands have to be ploughed at right angles to the ordinary run of the furrows. In highly farmed districts headlands are always cropped either with the field main crop or a catch crop, such as tares, for cutting green. If headlands are not cropped they should be ploughed and kept clean. A headland for horse work is usually about 5 yards wide, and about 8 yards for tractor work. Width is immaterial, provided the headland is ploughed and cultivated as thoroughly as the rest of the field. There are no headlands in a field which is ploughed round about. (See Ploughing.)

HEAT—A form of energy into which all others can be quantitatively converted. It is more difficult to conceive of heat in this way than in the usual manner in which it is wont to be brought before the mind's eye, as a subtle "something" possessed by hot bodies in greater measure than it is by exactly similar cold ones. One has to remember, however, that heat is nothing more than molecular motion, which only ceases when the temperature of a body is reduced to the absolute zero ($-273°$ C.). If it were possible to reduce a body to this temperature, it would, so far as we can see, be quite devoid of heat. Heat and temperature must be clearly distinguished, the latter may be conceived of rather as *fullness with heat*, and is scientifically defined as that property of a body in virtue of which it is able to part with heat to a second body in contact with it, which may then be said to be at a lower temperature than the first. Radiant heat is better regarded as radiant energy. (See Energy and Heat, Latent.)

HEAT, ANIMAL—In most of the animals with which the farmer is concerned the body temperature is maintained at some nearly constant point. This faculty of maintaining a constant temperature, usually considerably above that of their surroundings, is one common to all the higher animals. A very little way lower down the scale of evolution, however, there is found another type entirely, called cold-blooded animals, which includes reptiles and fishes, in which the body temperature follows fairly closely that of the surrounding medium, usually maintaining itself about 1° above this. Although a sharp and just distinction is usually drawn between poikilothermic (cold-blooded) and homoiothermic (warm-blooded) animals, it is well to remember that there are many genera which have to a greater or less extent the properties of both types. Thus, the CO_2 production and therefore

HEAT, ANIMAL (*Continued*)—

heat production of the earthworm is fairly constant between 10° and 22° C., although it must be classed as cold-blooded; the temperature of *Echidna* rises 10° C. with an external temperature rise of 30° C.; even in marsupials the regulation of heat loss is not fully developed. Again, there are many animals which hibernate, like bears, hedgehogs, bats, and dormice, and it is found that they behave as homoiothermic in summer and poikilothermic in winter. Kittens, rabbits, and puppies are cold-blooded at birth, while it is a commonplace of surgery that warm-blooded animals, even human beings, exhibit poikilothermic tendencies under prolonged, deep anæsthesia; hence the necessity for heating operating theatres. For a further discussion of these matters see R. Tigerstedt, "Handbuch vergl. Physiol.," III., ii., 1 *et seq.*

The body temperature even in warm-blooded animals is not maintained absolutely constant, however, and varies even in man when in perfect health by as much as 1° C. in a daily rhythm, with a maximum in the daylight working hours and a minimum about 4 a.m. This rhythm follows that of activity, however, and is not dependent on daylight, as may be seen from its reversal among night workers. In the following table the normal temperatures of farm animals, together with the range of normal variation, are shown. The figures represent the average of figures given by a number of authorities.

	Normal.	*Range.*
Horse	100°·3 F.	99°·7–101° F.
Ox	101°·4 F.	100°·5–102°·2 F.
Sheep	103°·1 F.	102°·3–104° F.
Goat	102°·5 F.	101° –104° F.
Pig	102°·4 F.	101°·7–103° F.
Dog	101°·3 F.	100°·5–102° F.
Cat	101° F.	100° –101°·5 F.
Fowl	106°·5 F.	105° –107° F.

The temperature of warm-blooded animals is kept constant by two regulating mechanisms. When the surrounding temperature sinks below a certain point, which differs with the kind of animal and with the conditions and which is called the *critical temperature*, the tissues begin to metabolize more quickly, thus generating more heat to keep the animal warm. On the other hand, if the temperature rises, the blood stream is diverted to a greater extent towards the surface parts of the body, thus ensuring a greater loss of heat which can be further increased by the outpouring of sweat which requires heat for its evaporation. The regulating mechanism is apparently controlled from a region of the brain at the anterior end of the corpus striatum in the region of the caudate nucleus, since Barbour (*Arch. Exp. Path.*, lxx., 1, 1912) has shown that if this region is cooled in a rabbit metabolism increases with rise of body temperature, while reverse changes are caused by cooling.

There are limits both of heat and cold which can be tolerated by warm-blooded animals; *c.* 45° C. appears to be the upper limit, the lower depends on natural and artificial insulation, the nature of the animal, etc.

HEAT, LATENT—When a solid is melted, it does not liquefy at once, but takes an appreciable time to do so, and this is so even if the whole mass is at its melting point. Similarly, a whole mass of water may be at boiling point, but heat has to be supplied for a considerable time to the mass to convert it all into steam at the same temperature. This is because the liquid, or vapour as the case may be, which is being formed absorbs heat in its formation without any rise of temperature. When the liquid solidifies again, this heat is given out, and again becomes apparent to the senses, and, of course, a similar thing happens when a vapour condenses. This heat which is occluded or stored away is known as latent heat. The heat energy is, of course, not destroyed, but remains in the liquid or vapour as additional energy of movement of the molecules, to which movement the liquid or gas owes its characteristic physical property of mobility. Of all substances, water appears to possess this ability to occlude heat, when changed from ice to water and from water to steam, to a greater degree than other kinds of matter, and the phenomenon becomes of importance to the agriculturist in a great variety of ways. When dew is deposited upon herbage, it is warmed in the process, or rather, is prevented from further cooling. The same thing applies to hoar frost in winter, as when the water vapour passes directly from the gaseous to the solid phase, both the latent heat of vaporization and that of fusion are given out at the same time, affording a very real protection to the more or less tender plant tissues. Again, water is continually transpired from the leaf surfaces, and in the process of its conversion to vapour the leaves are cooled, and it is, to a considerable extent, by these means that plants are able to withstand the great temperature changes to which they are subjected. In tropical countries, water-drenched matting is hung all round the verandahs of Europeans' houses so that the hot air may blow over them and thereby become cooled before reaching the occupants. Human beings and some animals are provided with sweat glands as part of their temperature regulating apparatus, and in this case also it is the latent heat of vaporization of the water in the sweat which is taken from the body and so cools it.

Instances might be multiplied almost without end, but the reader will have no difficulty in doing this for himself. Where a supply of really cool water is required in summer, a good plan, if ice is not available, is to place it, some time before it is needed, in an unglazed porous vessel where it is shaded from the sun but exposed to a slight breeze if possible. The water slowly percolates through the vessel and the sides become cooled by its evaporation. This process is largely used in India. Of course, water got direct from mains or from a deep well is likely to be as cool as, or cooler than, it is possible to make it in this way.

HENS—See Poultry, and Poultry Nutrition.

HERBS, GARDEN—See Market Gardening.

HOOF AND HORN—See Fertilizers, Miscellaneous.

HOPS—The cultivation of hops entails many specialized operations of which the grower must have a thorough knowledge, and in which his labourers must be skilled. Many of the practices are based solely upon empirical grounds; some, however, have received attention from the agricultural scientist, and upon these definite information is available.

Distribution—Hops are grown commercially in Australia, Austria, Belgium, Canada, Czechoslovakia, England, France, Germany, Jugoslavia, New Zealand, Poland, Russia, and the United States of America. The largest area under hops is in Czechoslovakia, Germany coming next with a slightly lower acreage. The greatest crop, however, is produced in the United States of America, closely followed by England. The fact that each of these countries produces a greater crop, on about two-thirds of the acreage in Czechoslovakia and Germany respectively, is accounted for by the fact that the Continental hops are grown without seed, which results in a lower crop per acre.

England produces nearly one-fifth of the world's supply of hops. These are grown in the following counties:

Hampshire	870	acres.*
Herefordshire	3,690	,,
Kent	11,770	,,
Surrey	140	,,
Sussex	1,700	,,
Worcestershire	1,730	,,
Other counties	70	,,

The yield varies widely, approximately from 5 to 25 cwts. per acre, the average for this country being about 12 cwts.

Soil Requirements—The hop is somewhat susceptible to climatic conditions, and for this reason its cultivation is localized in well-defined areas in all countries where it is grown. A further contributory cause of this localization is the difficulty of obtaining the necessary skilled labour outside a hop-growing area. The character of the soil is not supremely important; the essential requirements being depth, good drainage, and good water supply. In texture the soil may vary from heavy to medium loam.

Commercial Varieties of Hops†—The description which follows gives the more important characteristics of the best commercial varieties which are commonly grown in England. The characters of commercial importance in a hop are the following:

Order of Ripening—A knowledge of the order of ripening (although this character will vary to some extent with season, district, and treatment of the hop garden) is of use in helping a beginner in planting to arrange his garden so that the late hops may not be exposed by the picking of the earlies. It is, of course, necessary, with any considerable acreage, that the hops grown comprise early and late sorts;

* 1930 acreages.

† Use has been made of the article on this subject by A. Amos and E. S. Salmon, which appeared in the *J. Min. Agric.*, xxix., April, 1922.

HOPS (*Continued*)—

so that they can be picked, as they successively become ripe, without overtaxing the drying capacity of the oasts, as well as providing a reasonably long hop-picking season for the pickers.

Vigour of Growth—This character is of importance, since it largely determines the width of planting and the height of wire-work which should be adopted.

Suitability to Soil and District—For reasons which are little known, varieties are greatly influenced by these two factors, and a beginner should introduce a new variety to a district only after a thorough preliminary test.

Ease of Picking—This factor is important in the cost of production; some varieties can be picked much more cheaply than others.

Keeping Properties—A knowledge of this character gives a guide to the beginner in deciding the sequence of picking—some varieties will "hang," or "keep," much better than others. It should, however, be remembered that variety is not the only factor; other factors concerned are (1) absence of insect pests and of disease (Aphis, Mould, or Downy Mildew), and (2) character of soil.

Quality—This is a peculiarly elusive character, yet very important; it is likely to be particularly prominent in coming years. Owing largely to a lack of precise knowledge of the subject in the brewing trade, the commoner hops of poor brewing value have, in recent years, been more profitable to produce than the better varieties. The tide is now turning in the other direction.

Yield—This character, while affected within certain limits by various factors, is yet distinctive of the variety.

Early Varieties—**Prolific.** The earliest hop, with very large cones which are easily picked; crop heavily. Little grown on account of its poor quality.

Amos's Early Bird. Ripens a few days before the Bramling. Suitable for the best loams; grown in parts of Kent and Hampshire, and considerably in Herefordshire and Worcestershire. This variety, like the Bramling, is liable to be adversely affected by a cold or wet summer, when the cones may be small and difficult to pick. Highest quality.

Bramling. This variety is universally grown on the best soils throughout the hop-growing districts, but its acreage is unfortunately declining. Highest quality.

Midseason Varieties—**Tolhurst.** Grows vigorously on nearly all soils, crops very heavily and is easily picked. Quality poor. This was a favourite variety on account of its cropping powers, but it has now nearly gone out of cultivation owing to its lack of good brewing properties.

Mathon. Grown only in Herefordshire and Worcestershire on the best loamy soils; in some seasons inclined to make too much bine, which is not fruitful and, consequently, difficult to pick. Keeps well when healthy. Highest quality.

HOPS (*Continued*)—

Cobbs. Grown largely, especially in Kent, on loam and the lighter soils; grows vigorously and crops heavily; easy to pick, but does not keep well. Medium quality.

Tutsham. Very similar to the above; with better keeping powers. In order to counteract the tendency of this variety to produce, on strong soils, too much bine, it is the practice in some districts to "pull" the bines very hard and to train up only the latest bines. Medium quality.

Farnham Whitebine. Grown only in Hampshire and Surrey, on good loams. Highest quality.

Fuggles. Most suitable for heavy clay soils; grown almost to the exclusion of other varieties in the Weald of Kent and Sussex. Has a vigorous constitution, but is inclined to produce little bine unless stimulated by heavy nitrogenous manuring. Crops heavily in average seasons, and does well in wet seasons, but suffers in dry summers. Easy to pick; keeps well. Is a very good "copper" hop, and an excellent commercial variety for heavy soils.

Rodmersham Golding. Grown only on good loams in a few districts in Kent. Has a weak constitution, and the hills are liable to die away from "canker." Easy to pick; good quality.

Late Varieties—**Petham Golding and Canterbury Whitebine.** Grown only on the best loams, chiefly in Kent. Frequently grow too much bine, and in wet summers develop only a small crop. Although producing hops of the highest quality, the area devoted to the cultivation of these two varieties is now very small.

Colegates. The latest hop; grown in small quantity on heavy land, chiefly in the Sussex Weald and in Herefordshire. Crops heavily, but the cones are small. A "copper" hop.

Planting and Wiring—The plants, which are raised from cuttings consisting of the basal portions of the previous season's bines, are planted in spring. The distance apart is commonly 6 to 6½ ft. square. It is customary in England to include one male hop plant to every 150 or 200 female plants.

The fertilization of the female flowers results not only in the production of seed, but also in the more complete development of the cone (E. S. Salmon and A. Amos, *J. Inst. Brewing*, xiv., 311, 1908). This leads to a heavier crop of hops and, moreover, a greater weight of resins (the valuable part of the hop) per acre. The fertilization is of further advantage in that it shortens the duration of the "burr," which is very liable to become infected with the Hop Mould (*Sphærotheca humuli*). (See Fungus Diseases of the Hop.) English hops which have been fertilised usually contain about 20 per cent. (by weight) of "seeds" (A. H. Burgess, *J. Inst. Brewing*, xxxi., 623, 1925).

Short poles, about 8 ft. long, are provided to support the young plants. During the winter following planting a system of overhead wirework is erected on stout poles; coconut fibre strings (coir yarn) stretched from this overhead wire to pegs beside the plants ("hills")

HOPS (*Continued*)—

serve to support the bines during the second and succeeding years. The plants attain their full size in the third year.

There are three main types of wirework, the "Butcher," "Umbrella," and "Worcester" systems; these have been described elsewhere (A. Amos, Miscellaneous Publications, No. 42, *Min. Agric.*, 1925; A. H. Burgess, "Farm Crops," vol. iv., Gresham Publishing Co., Ltd., 1925). Experiments, carried out over a series of years, comparing these systems showed little difference in weight between the crops from the "Butcher" and "Umbrella" systems; the average crop from the "Worcester" system was about 1 cwt. per acre less (A. D. Hall, *J. S.-E. Agric. Coll.*, xii., 14, 1903). Hops on the "Butcher" system are less liable to damage by wind than those on the "Umbrella" system.

Cultivation of Soil during Growth—In spring the land is ploughed, away from the hills; this is followed by cultivation at intervals during spring and summer until about the end of July, the depth being gradually diminished at each succeeding operation. In the latter part of August the land may again be cultivated and thrown up into wide ridges by means of a special ridging plough, or, instead of this, the land may be ploughed in October, toward the hills; in either case the ridges formed serve to throw the winter rains away from the hills, which occupy the crests of the ridges.

About the end of June the bines reach the top of the strings, and lateral branches develop in the axils of the lower leaves. These leaves and laterals provide a home for fungus diseases and insect pests, as they are too low to be treated efficiently with spraying machines. It is, therefore, customary to remove both the leaves and laterals to a height of about 4 ft. In seasons favourable to growth this operation is accomplished without injury to the crop. On the other hand, in seasons when growth is poor the check, due to the removal of so many leaves and laterals, causes a noticeable reduction in crop, and it is probably better to carry out this "stripping" in two or three stages (A. D. Hall, *J. S.-E. Agric. Coll.*, xi., 7, 1902).

Manuring—Numerous experiments on manuring (A. D. Hall, *J. S. E. Agric. Coll.*, xii., 29, 1903) have shown the hop to be a general feeder, having no special manurial requirements. The manures to be used are, therefore, governed by the type of soil; the lighter soils generally respond to generous dressings of potassic manures, while those of the heavier type give good returns for liberal phosphatic manuring. All kinds of soil require fairly heavy dressings of nitrogenous manure annually; this constituent, however, must be used with caution, for excess will cause a too luxuriant growth of bine and leaves, which so excludes the access of light and air that the hops cannot develop or ripen normally. The liability to fungus diseases is also increased.

The annual manurial dressing on a soil, not particularly well supplied with either potash or phosphate, should contain about 350 lbs. nitrogen (=425 lbs. ammonia), 230 lbs. phosphoric acid (=503 lbs. calcium phosphate), and 200 lbs. potash (K_2O). Many

HOPS (*Continued*)—

different forms of manures are suitable for hops; farmyard manure, steamed bone flour, bone meal, meat and bone, fur waste, shoddy, guano, fish meal, meat meal, rape dust, basic slag, superphosphate, muriate and sulphate of potash, sulphate of ammonia, and nitrate of soda are popular among hop growers. The following is a typical system of manuring, per acre:

15 to 20 tons farmyard manure applied in late winter.
6 to 8 cwts. superphosphate.
1 to 2 cwts. sulphate, or muriate, of potash applied in February.
8 to 10 cwts. fish, or meat, meal applied in May.

A further dressing of 1 or 2 cwts. of sulphate of ammonia, nitrate of soda, or nitrate of lime is beneficial if the leaves show signs of yellowing, or if growth becomes slow; these manures, however, should not be used after about the end of June, or the colour of the hops may be adversely affected.

A periodical dressing of lime is essential, as the hop will not tolerate soil acidity.

Although many hop growers believe that organic manures are essential for hops, and go to considerable trouble to provide sufficient dung, or similar manure, it has been shown experimentally that hops can be grown for a period of years on mineral manures only, without reduction of crop or quality (A. H. Burgess, *J. Inst. Brewing*, xxxiii., 138, 1927). The mineral manures used in these experiments were sulphate of ammonia, sulphate of potash, and superphosphate, supplying approximately the quantities of nitrogen, phosphoric acid, and potash per acre stated above. Similar results have been obtained at the Weihenstephan Research Station, in Germany.

Harvesting and Drying—In September the hops ripen and are harvested. As soon as possible after they are picked the cones are conveyed to the kilns to be dried; if allowed to remain too long in a green condition they become heated and discoloured. The fresh cones contain about 80 per cent. of moisture, this is reduced by kiln drying to about 6 per cent.; after packing and storage the hops take up a small amount of moisture which varies according to the relative humidity of the air. The total moisture content of stored hops generally lies between 10 and 12 per cent.

Drying is the most difficult operation connected with hop production, and unless carefully carried out, the commercial value of the hops is greatly reduced; consequently, the process has been studied to a greater extent than have other branches of the industry.

The hops are placed upon a horse-hair cloth, supported by an open floor of battens laid on joists. A current of air, heated by an open fire or hot pipes, passes upward through this layer of hops and removes the moisture. The process occupies from eight to eleven hours.

As a result of systematic experiments, carried out under the auspices of the Institute of Brewing, much information has been gained concerning the effects of the various factors influencing the

HOPS (*Continued*)—

process (A. H. Burgess, *J. Inst. Brewing*, xxviii., 579, 1922; xxix., 403, 1923; xxx., 695, 1924; xxxi., 613, 1925; xxxiii., 58, 1927; xxxiv., 248, 1928; xxxv., 235, 1929). These are summarized below:

Work on the physical side has shown that the shallowest possible load of hops (one hop deep) requires a certain minimum time to dry, depending mainly on the temperature of the air and to a less extent on the speed and humidity of the air passing through the hops, and on the type of hops. For loads of greater depth the extra time necessary for drying increases in direct proportion to the depth; this extra time above the minimum is influenced mainly by the air speed, and, in a relatively smaller degree, by the temperature of the air.

The temperature of the air has a very marked effect on the minimum time of drying, and the period can be considerably shortened by the use of comparatively high temperatures (160° to 180° F.); the gain in time, however, is much more than counterbalanced by the depreciation in market value caused by the high air temperature.

The quality of hops is judged commercially by the colour, aroma, texture, and stickiness when rubbed in the hands. The value attributed to the colour and aroma decreases as the temperature of drying is increased, and, to obtain the highest market value, hops should be dried at as low a temperature as is practicable. The temperature should be kept particularly low (100° to 120° F.) during the first two hours after loading, or the colour will deteriorate. A temperature range which will give a reasonable output of dried hops of good quality, provided that there is a fairly good air current, starts at 100° F. and rises gradually to 160° F. at the end of the sixth hour. This temperature should not be exceeded, and it should be the aim of the dryer to keep as much below it as is possible consistent with getting the hops dried in a reasonable time. It has often been stated that the resins, upon which the preservative power of hops depends, suffer a depreciation in value when hops are dried even at fairly moderate temperatures. Experiments have shown, however, that drying temperatures up to at least 160° F. do not affect the preservative value of the hops; no difference in preservative value, determined by a biological method, can be distinguished between hops dried at various temperatures between 104° and 160° F. (*see also* H. V. Tartar and B. Pilkington, *Bull. No.* 114, 1913, *Oregon Agric. Coll.*). Hops dried at temperatures ranging from 160° to 212° F. show a slight reduction in preservative value.

It is customary to burn sulphur below the hops whilst on the kiln; the sulphur dioxide exerts a bleaching action, giving the hops an even yellowish colour; it also prevents the development of an odour resembling dried leaves. Sulphur is most effective when burned immediately the hops are placed on the kiln. The amount of sulphur required depends on the area of the kiln floor and the speed of the air in the kiln; satisfactory results are obtained by maintaining an average concentration of 1 oz. of sulphur dioxide per 1,000 cubic ft. of air for a period of forty-five minutes. The rate of drying is unaffected by burning sulphur.

HOPS (*Continued*)—

Utilization and Valuation—Hops are used by brewers for flavouring and preserving beer. The characteristic flavour is imparted by two classes of substances present in hops—essential oil and resin—both of which occur in the lupulin glands, which are borne at the base of the bracteoles and on the perianth of the female flower.

The essential oil varies in its constitution in different kinds of hops, each variety of hop possessing a more or less specific aroma. It is a mixture of several substances, and is present in very small amounts—0·2 to 0·5 per cent. of the weight of the dried hop. Most of it is evaporated when the hops are boiled in the wort; a portion, however, becomes converted into a non-volatile resinous substance which conveys an aromatic flavour to the beer (A. C. Chapman, "The Hop," The Brewing Trade Review, p. 61, London, 1905; and *J. Inst. Brewing*, xxxv., 247, 1929).

The resin is also a mixture which, for analytical purposes, is divisible into three portions named respectively α resin (or α acid), β resin (or β fraction), and hard resin (or γ fraction). The α and β portions are soft resinous substances, and it is these which possess preservative power; the hard resin is valueless in this respect. For many years the total amount of soft resin ($\alpha + \beta$) was considered to be the index of preservative value of hops. It was pointed out, however, by Ford and Tait (J. S. Ford and A. Tait, *J. Inst. Brewing*, xxx., 426, 1924) that the α and β fractions do not possess the same preservative power. The method described by these authors for the individual estimation of these fractions has been developed further by Walker and others (T. K. Walker, *J. Inst. Brewing*, xxxii., 486, 1926; A. H. Burgess and H. Martin, *J. Inst. Brewing*, xxxiv., 13, 1928; J. J. H. Hastings and T. K. Walker, *J. Inst. Brewing*, xxxv., 229, 1929), and is briefly as follows: The hops are extracted with cold methyl alcohol; the α resin is then precipitated as its lead salt, by means of lead acetate, from a portion of this extract. The weight of precipitate multiplied by 0·63 gives the amount of α resin. Another portion of the extract is diluted with water and shaken with petroleum ether; this extracts both α and β resins, the hard resin being insoluble in this solvent. The residue, after evaporation of the petroleum ether, therefore consists of $\alpha + \beta$ resin. The β resin is found by difference. The preservative value of the hops is obtained by adding the percentage of α to one-third of the percentage of β resin.

Although it is becoming increasingly more the practice to determine the preservative power of hops by analysis, yet the majority are still valued commercially by hand examination. The aroma, stickiness when rubbed, colour, texture, and resilience of the sample are noted; these give a fair approximation of the quality of the essential oil, the quantity of resin, and the efficiency of drying. A. H. B.

THE RAISING OF NEW VARIETIES OF HOPS FROM SEED—The varieties cultivated commercially have originated either as chance seedlings, *e.g.* Fuggles, or probably as "bud sports," *e.g.* Amos's Early Bird, of older cultivated varieties, and in all cases belong to

HOPS (*Continued*)—

the species *Humulus Lupulus* Linn. The raising of new varieties by hybridizing has been undertaken only at Wye College, where investigations were started about 1909. Observations which had been made on an American commercial variety (" Oregon Cluster ") growing at Wye led to the conclusion that the American plant (which had been named *H. americanus* by Nuttall in 1847, but which had since been united by botanists to *H. Lupulus*) represented a truly distinct species, characterized by differences in growth, leaf characters, and probably aroma. It was surmised that *H. americanus* crossed with *H. Lupulus* would be likely to produce hybrids showing new characters. During the past twenty years some thousands of seedlings have been raised, using these two species as parents. In new varieties an improvement is desired over existing varieties in (1) preservative properties, (2) aroma or flavour, (3) yield, (4) resistance to disease. The conservatism of the English market and the unwillingness to abandon traditional standards of evaluation are handicaps which have yet to be overcome.

(1) *Preservative Properties*—As is well known to brewers, American varieties (which cannot be grown in this country) are the richest in the world in preservative substances. Whilst English hops show on analysis 8 to 10 per cent., good American hops give 10 to 12 per cent. Hybrid seedlings have been raised, suitable for cultivation in this country, which equal, or exceed, the best American hops in preservative properties.

(2) *Aroma or Flavour*—Experiments have proved that the aroma carried by one of the parents used in crossing can be transmitted to the hybrid seedling, where it may be found combined with a character possessed by the other parent. Thus, in seedlings raised from an American commercial variety crossed with an English male hop, some will be found to possess the aroma of English hops transmitted by the male parent combined with the resins-producing character of the American female parent. Conversely, the American male hop confers the American aroma on many of the seedlings raised from English varieties.

(3) *Yield*—Very heavy yields are characteristic of many hybrid seedlings.

(4) *Disease*—Immunity to "mould" is shown by the " Golden Hop," a horticultural variety of *H. Lupulus* with yellow (" golden ") leaves, of no commercial importance. Breeding experiments have shown that green-leaved hybrids immune to Mould can be raised from this parent. These, however, up to the present have proved to be deficient in preservative properties. Male hops (American) have been discovered which are immune to Mould. Some resistance to Downy Mildew has been shown by a few seedlings. Most of the seedlings raised, of American and German parentage, have proved to be completely resistant to Mosaic Disease; these carry the virus, however, without showing any trace of it in their growth. This is probably due to the fact that American and German varieties are themselves "carriers" of Mosaic Disease. Several cases have occurred

HOPS (*Continued*)—

where new seedling varieties (" carriers ") planted out on farms in Kent have transmitted Mosaic Disease on a wholesale scale to the surrounding hops, while they themselves remained perfectly healthy. It is necessary, therefore, to plant these new seedling varieties either in gardens by themselves or adjoining Fuggles, a variety which is completely resistant to Mosaic Disease.

It will be seen, therefore, that success has been attained as regards most of the characters desired. The most promising seedling varieties are now being tested commercially at the Research Station, East Malling, and at Wye College, and also on different soils at various farms.

Further information will be found in the following publications: *J. Genetics*, iii., 195, 1914; xi., 241, 1921; *J. Bot.*, 132, 1915; *J. Agric. Sci.*, vii., 175, 1915; *Compt. rend. Trav. Lab. Carlsberg*, xi., 3, 1915; *J. Inst. Brewing*, xxiii., 60, 1917; xxxiii., 12, 570, 1927; *First to Twelfth Reports on the Trial of New Varieties of Hops*, 1918-1929, East Malling Research Station; *Ann. App. Biol.*, viii., 146, 1921.

E. S. S.

FUNGOUS DISEASES OF THE HOP—These fall into two classes: the major diseases are Mould and Downy Mildew, and the minor diseases Canker, Wilt, Leaf Spot, Grey Mould, and Hop "Drop." In addition there are three Virus diseases. (The article Insecticides and Fungicides should be read in conjunction with the following.)

Mould or Powdery Mildew—This fungus (*Sphærotheca Humuli* (DC.) Burr.), which is native to this country, is well known to every hop grower and has been the cause of immense losses. In the past the disease which this fungus causes has led to the grubbing up of hundreds of acres of hops. Now that a more scientific knowledge has been obtained of the life history of the fungus, the disease is very largely controlled by the adoption of preventive measures (*Min. Agric.*, Misc. Pub., No. 42, 1925). To the hop grower the disease is known under the two names of Mould or White Mould and Red Mould. As "mould" he observes it on the leaves, "burr" (inflorescence), and (more rarely) on the cones, in the form of a white growth, often powdery or mealy with masses of spores. As "red mould" he observes it on the ripening cones, the " petals " (bracts and bracteoles) of which, under the attacks of the fungus, turn a reddish-brown colour.

The life history of the fungus is as follows: About May, winter spores (*ascospores*), arising from fruit bodies in the soil, infect the lower leaves on the hop bine (stem), and white spots or patches appear. These spots consist at first of superficial spawn (*mycelium*), which soon, however, produces hundreds of upright branches (*conidiophores*), each with a necklace-like chain of summer spores (*conidia*) at its tip, a stage which can easily be seen with a pocket magnifying glass. It has been computed that on a square inch of mildewed leaf surface no less than 2,800,000 spores may be produced during the season. Each spot of "mould," under suitable weather conditions, soon becomes densely powdery with accumulated spores; it is then that

HOPS (*Continued*)—

the disease is recognized by the hop grower as being "on the run" and threatening his crop with disaster. The conditions which appear to be the most favourable to the spread of Mould are damp or showery weather alternating with bright sunny days. As soon as the spore is ripe, it becomes detached, and is carried by the wind, often to considerable distances, to healthy hop plants, where it causes a fresh outbreak of disease. If not dealt with, the disease spreads from the lower leaves to the upper, and if spores reach the inflorescence ("burr") irreparable injury is caused, since an infected inflorescence is unable to develop into the hop cone, and becomes converted into a hard, white knob. The cones also, when approaching ripeness, are liable to be attacked by spores, in which case their healthy yellow-green colour changes to reddish-brown, an appearance attributed by the grower to the action of Red Mould. This is the most insidious form of the disease, and can only be prevented by the rigorous suppression of White Mould earlier in the season. During the latter part of the summer and in autumn the fungus ceases to produce summer spores, and develops on the mycelium minute, dark-brown, globular fruit bodies (*perithecia*). These are found, usually densely clustered, on the leaves, stem, and (often in great profusion) on the "petals" of the hop cone. Each fruit body contains a sac (*ascus*), holding eight winter spores (*ascospores*), and is thick-walled, and remains through the winter closed and impervious to the weather. In the spring months, under the influences of higher temperature and moisture, the fruit body cracks open, the contained sac emerges, and swells considerably (through its wall taking up moisture) until so much tension is set up that the sac bursts and violently ejects the winter spores into the air. These are carried by currents of air to young hop leaves, and at once infect them, producing in ten days or so spawn with *conidiophores* bearing chains of summer spores, thus completing the cycle of the life history.

The measures for controlling the disease fall into two classes: direct and indirect. The direct measures consist in the use of sulphur, applied as a dust either in the form of "flowers of sulphur" (pure sublimed sulphur) or the finest ground sulphur. The first sulphuring should be given when the bine is breast high, and even earlier where bad outbreaks of mould have occurred. It is a common fault to omit this early application of sulphur, and it is often dearly paid for. If the early outbreaks are suppressed by the timely use of sulphur, there is little fear of serious ones occurring later, unless spores are blown in from adjacent diseased gardens. Further sulphurings should be given from time to time, choosing windless days; it is the practice of many good growers to sulphur when the hops are in "burr." If necessary, applications can be given when the young cones have formed, but no sulphur should be applied to the ripening cones, as many brewers strongly object to the presence of free sulphur in the dried article. When the bine is young, knapsack sulphurators may be used, but later applications require to be made with a "horse sulphurator." Whilst in dry weather sulphur in dust form proves a perfectly reliable remedy,

HOPS (*Continued*)—

in periods of wet weather it may be advisable to use a sulphur wash, such as "liver of sulphur" (polysulphides of potassium or sodium), or the so-called "colloidal" sulphur. Indirect measures comprise (1) the early "stripping" of the lower leaves of the bine, and the removal of "runners" during the summer; (2) the destruction of mouldy cones and bine; (3) avoidance of systems of training in which the bine gets matted together at the top—a condition known as "housed in"; (4) adoption of a system of balanced manuring, in which the effect of nitrogenous manures is counteracted by that of phosphates and potash; (5) extirpation of "wild" hops in adjacent hedges and waste places. The necessary number of male hops ("seeders") should be provided in every hop garden; a critical period for infection by mould is when hops are in "burr," and this period is appreciably shortened by quick fertilization.

Downy Mildew—The Downy Mildew of the Hop (*Pseudoperonospora Humuli* [Miy. et Tak.], Wils.), a native of Japan and North America, has within recent years spread into Europe. The first recorded appearance in Europe was in 1920, in the experimental hop garden at the South-Eastern Agricultural College, Wye, Kent (*Ann. App. Biol.*, xii., 121, 1925). In 1923 it was discovered in hop gardens in Germany and Yugoslavia, and by 1924 it had reached commercial hop gardens in Kent. The fungus appears to have been introduced into Europe on hop plants or seeds imported from Japan or North America, although the theory has been put forward that it may have spread by natural means from Asia to Europe, via Yugoslavia. In all the hop-growing countries in Europe in which the Downy Mildew has appeared, considerable alarm is felt at the damage to the hop crop inflicted by this new disease. The loss caused by Downy Mildew in Germany in 1926 has been estimated at over 1¾ million pounds sterling. In the famous hop-growing district of Hallertau (where some of the finest hops in the world are grown) experience has already shown that, under the climatic conditions obtaining there, as many as ten sprayings may be required during the season to secure the crop in a healthy condition. The heavy cost of these treatments is leading to a search being made for a variety less susceptible to the disease. In this country, owing to lack of experience, it is as yet impossible to gauge the effects which the Downy Mildew will have on hop growing, but some of the most observant growers hold the view that this disease is the greatest danger threatening the future of the industry. Like all the members of its class, the Downy Mildew of the hop may be termed a "wet-weather disease," and its effects on both bine and cones are most to be feared in wet years. In the wet season of 1927 the disease overran many gardens in Kent and the adjoining hop-growing counties, and just before and during picking time the hops were suddenly turned brown and ruined, which led to the crop over some hundred of acres being left unpicked. In some seasons severe injury to the young bines may be caused so that a deficiency results at training-up time (*J. Inst. Brewing*, xxxv., 20, 1929, xxxvi., 1930).

HOPS (*Continued*)—

A knowledge of the main facts of the life history is essential for the carrying out of the necessary control measures ("The Downy Mildew of the Hop," Leaflet, *South-Eastern Agric. Coll., Wye*, 1927). The first sign of the presence of the disease appears in April or May, when some of the hop shoots just breaking through the ground are seen to be abnormal, being thickened and spike-like, with shorter internodes and smaller leaves, and of a silvery or greyish-green colour. These diseased shoots, termed "basal spikes," contain spawn (*mycelium*) in their stems, and a blackish mass of spores is soon produced on the surface of the stem and its stipules and on the under surfaces of the leaves. The disease is spread rapidly, by the agency of these spores, to neighbouring shoots, so that fresh "spikes" soon appear. The trained-up bine, when 5 to 7 ft. high, is frequently attacked at the tip, which becomes completely arrested in growth and spike-like—the so-called "terminal spike." These spikes must all be removed, and if no spare bines are available, a healthy lateral shoot which develops below the spiked tip must be trained up. In all cases the fungus produces, sooner or later, according to weather conditions, spores on the parts of the bine attacked. On the leaves of otherwise healthy bine infection results in the production of dark, angular spots (which often ultimately coalesce into larger patches), on which more spores are produced. The leaves of terminal spikes, and also of lateral spikes, when these are produced, frequently become blackened on the lower surface by a profusion of spores. On the Continent the "burr" is commonly attacked, and the production of cones entirely prevented, but this form of the disease has so far been little in evidence in this country. The cone is liable to be attacked in all stages of development; if the cone is not fully grown when it is attacked, it becomes hardened and distorted, while the "petals" of the ripe or nearly ripe cone may be turned a dirty brown colour within two or three days. In wet weather spores are produced freely on diseased cones. The spores are distributed by wind over longer distances and in drops of water from plant to plant during wet gales. In common with all Downy Mildews, the spore produces on germination in water a number (four to seven, or more) of minute "swimming spores" (*zoospores*). Each of these, after a period of active movement, comes to rest, and proceeds to infect a healthy leaf, shoot, or cone, producing spawn and, within a week, fresh spores. Thick-walled resting spores (*oospores*) are found in the tissues of the leaf, stem, and cone. The resting spore on germination gives rise to *zoospores*. The spawn is able to hibernate in the buds on the rootstock of the hop, and to some extent within the tissues of the rootstock. It may penetrate to the roots, and cases have been recorded where the plant has been killed.

The control measures consist of (1) removal of diseased parts, and (2) preventive spraying with Bordeaux mixture. Every effort should be made to remove all basal spikes before they have produced spores; as by such action the infection of healthy bines and further production of spikes may be prevented. The search for, and removal of all "spiked" growths should be continued through the season. Workers

HOPS (*Continued*)—

removing spikes should not train up the bine, as their hands may be contaminated with spores. Spare bines should be left for use if necessary. The lower leaves of the trained-up bines should be stripped off to a height of 5 ft. as soon as it is safe to do so. Any lateral shoots that arise from the stripped bine should be removed, as well as all "runners" growing from the "hill." Four sprayings with home-made Bordeaux mixture should be given: (1) when the bine is three-quarters up; (2) when the bine has reached the top; (3) just before the hops have come into full "burr"; (4) immediately the burr stage has passed. A fine, misty spray is essential for efficient protection of the bine, such as is given by motor- or horse-drawn "hop washers," fitted with special nozzles. The recently invented Bordeaux Spray Blower, attachable to any machine, greatly facilitates the work. Home-made Bordeaux mixture has proved to be the best fungicide for use through the growing season; for special use in sudden attacks on the nearly ripe cones, trial may be recommended of a ½ per cent. solution of soft soap, as it has been found that very weak soft-soap solutions kill the swimming spores (*zoospores*) instantly (*J. Agric. Sci.*, xix., 185, 1929). All commercial varieties of hops are susceptible as regards attacks on the bine and leaves, but the variety Fuggles is resistant as regards attacks on the cones, and does not therefore require to be sprayed.

"Canker" or "Growing off"—This disease is characterized by the sudden "wilting" and dying of one or more bines in the "hill," which may take place from as early as June up to the time when the bines are bearing hops. The affected bines are usually found to be almost severed at the base, and with a slight pull easily come away from the rootstock. Examination shows that the rootstock is "cankered" in the vicinity of the dying bines, the tissues being brown and dead. Whitish pustules of the fungus concerned, known as *Fusarium* in this stage, appear on the dead basal parts of diseased bines. The *Gibberella* stage of the fungus, in which small, densely clustered, dark-purple fruit bodies enclosing winter spores (*ascospores*) are produced, is found not uncommonly on cut-off diseased strap-cuts lying about in the garden. The varieties Bramling, Rodmersham Golding, Mathon, Farnham Whitebine and Tolhurst are the most susceptible.

Control Measures—Hard "cutting" or "dressing" of the hills should be adopted, all the browned parts being pared away; all dead hills should be grubbed up and burnt. The cuttings from all hills in the affected parts of the garden should be collected and destroyed. The disease is favoured by moist conditions; consequently drainage, or suitable cultivation to remove the moisture of wet land, will help to keep "canker" in check.

"Wilt"—This disease, caused by *Verticillium albo-atrum*, Rke. et Berth., is at present known only in the variety Fuggles, and from two localities (Kent and Herefordshire). The symptoms appear when the bines are carrying hops; one or several, or even all, of the bines of a hill

HOPS (*Continued*)—

"wilt," the leaves yellowing and withering. The diseased bines on being pulled come away very easily, and invariably bring a piece of the crown of the rootstock with them. The tissues of the crown turn brown and decay, and the whole hill may be killed. Prompt grubbing up and burning of affected hills are to be recommended.

Leaf Spot—Circular spots, $\frac{1}{20}$ to $\frac{1}{5}$ in. in diameter, consisting of a whitish central portion, bordered by a dark, purplish-brown line and surrounded by a yellowish zone, appear on the leaves and, if sufficiently numerous, cause large yellow areas. These spots are caused by the presence of the fungus *Cercospora Cantuariensis*, Salm. et Worm.; large brown spores are produced on the under surface. The disease was first found in a hop garden at Canterbury, Kent, on the variety Canterbury Golding, and no serious damage has been reported. In 1927 the disease was reported from Hampshire.

Grey Mould—In wet seasons, or where overcrowding of the bine occurs, Grey Mould (*Botrytis cinerea*) is occasionally to be found attacking the hop cone; the part attacked is invariably the tip, which turns prematurely brown. The disease has been observed on the varieties Tutsham, Cobb's and Tolhurst, but the injury caused up to the present has been too slight to warrant the taking of preventive measures.

"Hop Drop"—The disease manifests itself by causing nearly ripe hop cones to fall to the ground in considerable numbers. The fungus, a species of *Macrosporium*, attacks the stalk bearing the cone, and a brown discoloration, on which spores are produced, results at about $\frac{1}{2}$ inch below the hop. It is possible that hops are attacked only when affected by cold, wet weather. The disease has been noted only from a farm at Canterbury, on the varieties Canterbury Golding and Cobb's.

VIRUS DISEASES OF THE HOP—Within recent years the known Virus diseases of the hop, in common with those of other plants, *e.g.*, the potato, tomato—have increased in number (see Potato; Tomato under Glasshouse Crops; Sugar-Beet). Three diseases definitely belonging to this class are now recognized: "Nettlehead," Mosaic and Chlorotic Disease. A fourth, "Split Leaf," characterized by the appearance of fissures or holes in the leaf, which is of common occurrence in the variety Fuggles, probably belongs also to the Virus group (*Ann. App. Biol.*, xiv., 175; xv., 342; xvi., 359, 1927-1929).

Whether the hop Virus Diseases are specific, *i.e.*, confined to the hop plant, is not yet known. In the majority of the virus diseases, the virus (believed to be an ultra-microscopic organism carried in the sap) is transmitted from diseased to healthy plants by insects, frequently Green Fly (*Aphides*), or spread from plant to plant by contaminated sap on the hands of workers, as in the tomato and tobacco virus diseases. It is not yet known how the hop virus diseases spread in nature; it is possible that in the processes of "stripping" the bines and in cutting or "dressing" the hills, infected sap may be carried to healthy plants by the hands or knife. Workers at Wye have shown that the three virus diseases of the hop are transferable by grafting.

HOPS (*Continued*)—

"**Nettlehead**"—This disease is of long standing, having been known for sixty years and more in gardens of Fuggles, to which variety it appears to be confined. Affected plants show a difference in the shape of the upper leaves, which become more deeply divided, with the margins incurved. The bine also is affected in a characteristic manner: it fails to reach the top of the pole or wirework, and often stops short at about 5 ft., and the tip ceases to climb and hangs down. No cones, or only a few poor ones, are produced. The disease appears first on a few plants here and there in a garden, and then slowly spreads year by year; it is not usually fatal, but affected plants never recover. No cure is known; diseased hills should be grubbed up and fresh sets planted. Care should be taken not to propagate from affected hills or from those in their vicinity.

Mosaic Disease—The first record of the occurrence of this disease was about twenty-five years ago. At the present time it is not widespread, but where it has occurred serious losses have resulted. Unlike "Nettlehead," this disease is invariably fatal, the hill being killed in two or three seasons. When it appears in a garden, it quickly spreads from one hill to the next, and the greatest difficulty is experienced in checking it, even though all plants visibly affected are grubbed up as soon as observed. Plants severely affected are entirely barren; the bines are shortened, more or less rigid, and cease to climb; the leaves are brittle, mottled with Mosaic-like markings, and their margins are more or less recurved. Not infrequently the tip of the bine dies back for several inches. Plants slightly affected show Mosaic-mottled leaves on a few lateral branches only, and sometimes a characteristic malformation of the cones. Such plants the next season show the disease in a severe form. All the commercial varieties are susceptible, except Fuggles and Tolhurst. Experiments at Wye have shown that when scions of these two varieties are grafted on plants carrying the virus of Mosaic Disease, they remain healthy and complete their normal development.

Mosaic-affected plants should be grubbed up at once, and it is probably a sound plan to grub up also the hill on either side. An inspection should be made just before hop-picking, and plants slightly attacked should be marked for grubbing up after their hops have been picked. No cuts should be taken from any hills in a garden in which Mosaic Disease is present.

Chlorotic Disease—This disease is of recent occurrence, and is known at present only from one locality, in a hop garden in Worcestershire of the varieties Fuggles and Mathon. Affected plants show a weakness of growth, and the leaves are more or less distorted in shape, being puckered and blotched with conspicuous yellow (chlorotic) markings.

Further information is obtainable in the following publication: *J. Min. Agric.*, xxxi., 1144; xxxii., 30; xxxiii., 149, 1108, 1925-1927.

E. S. S.

HOPS (*Continued*)—

INSECT PESTS OF THE HOP—Forty-five species of insects have been found feeding on hops; some of these are very destructive, others of only local importance, and a few of rare occurrence. The most serious pests are the Hop Aphid (*Phorodon humuli*), the Dark and Green Needle-Nosed Hop Bugs (*Calocoris fulvomaculatus, Calocoris norvegicus*), the Frog Fly or "Jumper" (*Euacanthus interruptus*), Wireworms (*Elateridæ*), the Hop Flea Beetle (*Psylliodes attenuatus*), Strig Maggot (*Contarinia humuli*), and the Red Spider (*Tetranychus telarius*). A full list of the others is appended. (See in this connection Insecticides and Fungicides; Insect Pests, Measures of Controlling; Plant Diseases and Pests, Legislation with Reference to.)

The Hop Aphid (*Phorodon humuli*)—This Hop Aphid is by far the worst hop pest, not only in England but in all hop-growing countries. Before spraying became general the crop was often entirely destroyed by it (a "black blight"). In 1882 alone, the damage in England caused by it was estimated at £1,750,000. The life-history is now well known. The winter is passed entirely in the egg stage on various prunes, especially sloe and damson. At one time some were considered to hibernate in the soil, and come out early and attack the shoots. Recently it has been shown that the early green aphides on the shoots are the *Macrosiphum gei* of Koch, which feeds on many plants; they cause the young shoots to become stunted and brittle. These become winged early in the summer and fly away, and, in consequence, are not very harmful. *Phorodon humuli* hatches out on the prunes in the spring and feeds under the leaves, which it does not curl up. In all its apterous stages it can be told by the prominent processes on the head and basal segments of the antennæ. The ova may hatch out between mid-March and the end of April. By early May the apteræ enter the pupal stage, wing buds appear, and by mid-May the first alatæ occur. These alatæ fly off to the hops, and may migrate all at once or over a protracted period. The chief migration to the hops ends by mid-June, but migration from the prunes have been known as late as August. Most of the late migrations "fly" that settle in the cones and produce "brown hops" come from other hops, both cultivated and wild. The winged females or "fly" first settle on the tops of the bine and shelter in the folds of the tender leaves, and produce the "lice" or viviparous young. Many of the mid-migrations settle under the lower leaves, and as these are difficult to hit in washing they are best stripped off. From the time of hop picking until October the apteræ on the hops produce alatæ—return migrants—which return to the prunes and produce young, which later become oviparæ. Later these are joined by alato males and the resulting ova are laid on the prunes. Besides feeding on hops and prunes, it has been found breeding on nettles and apple (F. V. Theobald, "The Plant Lice or Aphididæ of Great Britain," vol. ii., p. 276, 1926; and *Rept. Econ. Zool. for* 1912-13, p. 23, 1913).

Prevention and Treatment—As a control, washing with quassia and soft soap was at first used and was largely effectual, but recent work

HOPS (*Continued*)—

has shown that nicotine and soft soap is much better. At first 6 ozs. of 98 per cent. nicotine to the 100 gallons of soap wash was used, more recently 3-4 ozs. of nicotine has been found equally successful. Some growers prefer dusting, and then a 3 per cent. nicotine dust is recommended, but much depends on the "duster" used; special machines like the "Niagara" duster will put on a sufficiently dense cloud to hit practically all the lice. In the last two years pyrethrum wash has been used experimentally and found quite successful (Austin, *J. South-East. Agric. Coll.*, No. 25, pp. 59, 67, 1928; No. 26, pp. 124, 135, 1929). Where damsons or plums are grown near or between hops they should be winter-sprayed with a tar distillate, and any sloe hedges around the gardens, to kill the winter eggs. *Natural Enemies*—Much good is done by certain insect enemies, such as lady-bird beetles and their larvæ (niggers) or *Coccinellidæ*, which devour countless aphides. In Bavaria these insects were relied on to control the pest, but in 1929 no ladybirds appeared, and recourse was then made to spraying. Other parasites occur, but they are not of such importance.

Needle-Nosed Bugs (*Calocoris* spp.)—Two species of Capsid Bugs (*Capsidæ*) commonly attack hops: (1) the Dark Needle-Nosed Bug (*Calocoris fulvomaculatus*), and (2) the Green Bug (*C. norvegicus*). They both occur almost entirely in poled gardens, but the latter has been found in wired gardens. They both damage the hops by puncturing the bine and causing it to cease to revolve, and often kill the tips, and (2) by puncturing the leaves, which punctures produce holes.

The young wingless insects commence to feed in late May and are not very active, but when they become mature and dark, as in *fulvomaculatus*, they are very active and run around the poles, and at this time are spoken of as "shy bugs"; both *fulvomaculatus* and the green *norvegicus* appear as adults by the end of July. They both feed on many other plants besides the hop. Their long sausage-shaped eggs are laid in the hop poles and any dead wood near-by. The ova have recently been shown by Steer (*Ent. Mo. Mag.*, lxv. 3, 1929) to be laid deep in the wood of the poles, and they have also been found in old pieces of bine (*Min. Agric.*, Misc. Pub., p. 66, 1925). In the poles they are carried from garden to garden.

Control is by spraying when in the young stages with 12-16 ozs. of nicotine plus soap to the 100 gallons of water. The adults are very difficult to kill. Poles in infested gardens should be drenched with a 10 per cent. tar distillate wash when stacked.

The Frog Fly (*Euacanthus interruptus*)—This insect, also known as the "jumper," occurs now and again in harmful numbers in Kent, Sussex, and Hampshire, less frequently in the West. The young apteræ by constant sucking stunt the bine and turn the leaves yellow (yellow blight), the bine ceasing to revolve. The pale young crawl about, but the coloured adults are very active and jump about. The winged adults have the front wings yellow, with a long wedge-shaped dark area, another dark one below, and some with red marks

HOPS (*Continued*)—

on the forewings; the hind pair transparent. Attack usually starts when the hops are a few feet up, and growth is at once held up, a bushy appearance resulting, and the cause is often overlooked by growers. It is usually epidemic in poled gardens, but now and then in wired ones. Winter is passed in the egg stage in the poles, and, like the former, it is carried about in them.

Treatment with 3 per cent. nicotine dust to kill the young has been found successful in recent years. For destroying the jumpers no wash has yet been found quite successful, and recourse has to be made to jarring over tarred sacks.

Wireworms (*Elateridæ*)—Wireworms, the larvæ of Click Beetles (*Elateridæ*), often feed on hop roots, attacking the fibrous mass and the larger roots, even burrowing into the latter. Young hop sets are often killed by them. Three species are found feeding on hops: *Agriotes sputator*, *A. obscurus* and *Athous hæmorrhoidalis*, and, rarely, *A. lineatus*. The damage is worst in hops planted on recently broken pasture-land. The Click Beetles appear mostly in June and July, but may be found at all times of the year, as they hatch out in the soil a long time before they come above ground. The females lay their eggs in or on the ground when clean, as well as when foul with weeds, but they certainly prefer the latter, and pasture and clover ley. The Wireworms feed for three to five years, and do so most of the year, except when moulting their skin. In hop gardens they collect in and around the hills, especially when well cultivated. When ready to pupate, they go deep into the soil. It is no unusual thing to find fifty in a single hop hill. Roebuck has shown (*J. Min. Agric.*, xxx., 1049, 1924) that below 100,000 to the acre they need not be feared, but in hop gardens, as they concentrate in the hills, much smaller numbers than in pasture do infinite harm. The best treatment in hop gardens is still trapping with pieces of turnip, mangold, or carrot put in the hills. Some good has been done by the use of naphthalene at the rate of 3 cwts. to the acre, around the hills. Other substances have been recently tried, but did not prove very successful. Considerable good is done in hop gardens by catching the adults by putting small heaps of clover and lucerne here and there covered with tiles, which attract the Click Beetles in June and July, which are then easily collected and destroyed. Moles do enormous good, and should be encouraged.

The Hop Flea (*Psylliodes attenuatus*)—Hops are frequently damaged by Flea Beetles (*Halticidæ*). The species found are *Psylliodes attenuatus* and *Plectroscelis concinna*, the first being the most important, and is the true "Hop Flea." The Flea Beetles do damage by eating holes in the young leaves, and destroy the shoots by biting them. Late in the season they also riddle the cones. The beetles pass the winter amongst vegetal and other refuse around the gardens, especially amongst nettles. On the first warm days of spring they begin to feed on the young nettles, and as soon as the hop shoots come up they fly to them and continue feeding until late May, when they lay their

HOPS (*Continued*)—

eggs in the soil, and the larvæ feed on the hop roots and pupate there. These pupæ hatch in August and September, and at this time the "fleas" attack the cones and then go into winter quarters, but may continue to feed on nettles until late in autumn. According to Newton (*J. South-East. Agric. Coll.*, No. 26, p. 157, 1929), the complete life-cycle took eighty-four days in the laboratory, but he says would be less in the open (sixty-seven to seventy-one days, according to Tölg). There is only one generation annually.

Treatment consists of burning debris around the gardens, nettles especially, keeping chicks in them when the shoots come up, and dusting with fine naphthalene in dull weather. Good results have also been obtained by spraying with arsenate of lead.

The Strig Maggot (*Contarinia humuli*)—This cecid fly is only of occasional importance. It occurs most frequently in Worcestershire and Herefordshire, but now and then attacks occur in Kent and Surrey. This small midge oviposits in the young hops, commencing its attack when the hops are in "burr." The maggots feed in and around the strig of the cone and turn it black, and also at the base of the bracts and make them brown and they fall off. As many as fifty have been found in a single cone. The attack is first noticeable in early August, and the white maggots become mature in September, and then skip down to the soil and bury themselves 2-4 ins. deep, and in a few weeks make a transparent puparium, in which they remain all the winter. This insect was described by the writer from the larvæ as *Diplosis humuli* many years ago. Barnes has recently shown (*J. South-East. Agric. Coll.*, No. 24, p. 122, 1927) that Tölg described the adult in 1925, so that the name *humuli* stands to Tölg and not to the present writer.

The only two methods of treatment are by applying finely powdered naphthalene at the rate of 3 cwts. to the acre to the hills before the larvæ enter the puparium stage, and by folding sheep in invaded gardens during winter.

Leather Jackets (*Tipula oleracea*)—The grubs of the Crane Fly often attack the roots of young hops. Recent experiments have shown that they may be controlled easily by the usual poison bait of bran and Paris green commonly used to control this pest in the field. Another larva frequently found devouring hop roots is the *Chafer larva*, the grub of the Cockchafer (*Melolontha vulgaris*), which may be destroyed by hoeing in naphthalene, about ½ lb. to the hill, in winter.

Red Spider (*Tetranychus telarius*)—This often serious hop pest was formerly known as *Tetranychus altheæ* V. Hanst. It has now been proved to be the common species *telarius* found on a great variety of plants. It is especially harmful in hot, dry weather. The minute mites (0·5 mm. in length) vary in colour from green with red spots to yellowish-green, almost transparent, and bright red late in the season. They attack the under surface of the leaves and cause them to become pale and mottled, then brown or reddish-brown, and covered

HOPS (*Continued*)—

below with a fine silken webbing. When plentiful, the webbing spreads from bine to bine at the top of the hops and is very noticeable. Beneath this silken tent the mites lay their eggs in summer, and the mites in all stages are found there. Winter is passed in the adult stage, mainly in cracks and crevices of the poles, under any bark on them, in stubs and debris on the ground, and even in crevices in the soil. In gardens they have been found in great numbers in the spring, left on the wires and on the large posts. Many may hibernate on various wild plants round the gardens.

Treatment consists of dusting or washing with various forms of sulphur, such as liver of sulphur ½ lb. to 100 gallons of water, or colloidal sulphur as a dust. Good results have been obtained with lime sulphur 1 gal. to 100 and flour paste 6-100. Poles, string, etc., should be cleaned in the winter, the former by washing with tar distillates, and the string burnt off the wires.

Other Insects found Feeding on Hops—Peacock Butterfly (*Vanessa io*), Comma Butterfly (*Vanessa comma*), Rosy Rustic Moth (*Hydrœcia micacea*), Yellow Underwing (*Typhæna pronuba*), Quaker Moth (*Tæniocampa munda*), Clouded Drab Moth (*T. instabilis*), Ghost Moth (*Hepialus humuli*) (on rootage); Cinnabar Moth (*Euchelia jacobeæ*), Pepper-and-Salt (*Amphidasis betularia*), Hop Dog (*Dasychira pudibunda*), Dock Moth (*Acronycta rumicis*), Pug Moth (*Eupithecia assimilata*), Eyed Hawk Moth (*Smerinthus ocellatus*), Vapourer (*Orgyia antiqua*), Gold Tail (*Porthesia similis*), Snout Moth (*Hypena rostralis*), *Tortrix podana* and *T. heparana*, Clay-coloured Weevil (*Otiorhynchus singularis*), *O. sulcatus, Plinthus caliginosus, Liophlæus nubilus. Aphis rumicis, Lygus spinolæ* and *L. pabulinus, Bibionid larvæ*, Earwigs (*Forficula auricularia*), Spring Tails (*Entomobrya nivalis*), Slugs (*Agriolimax agrestis*), and Millipedes. (See *Min. Agric.*, Misc. Repts., No. 32; *J. South-East Agric. Coll., Wye*, No. 25, p. 71, 1928, and No. 26, p. 104, 1929; *Rept. Res. and Adv. Dept. South-East. Agric. Coll.*, p. 6, 1929; *Entomologist*, vol. lix., p. 129, 1926; vol. lxi., p. 121, 1928; vol. lxii., pp. 7-10, 1930.)

F. V. T.

HORSE-RADISH—See Market Gardening.

HORSES versus TRACTORS—The horse is still the principal source of tractive power in British agriculture, and with few exceptions tractors are used mainly to supplement the work of the horse teams, especially in performing heavy and urgent duties during tillage and harvest operations. The rapid displacement of horses by motor vehicles in commercial transport and the general tendency to mechanization in industrial concerns, however, naturally raise the question as to whether there are sound economic reasons for the present relative importance of horse and motor power in British farming.

It cannot be said that the predominance of the horse is due to farmers' lack of knowledge of the merits of tractors, or that the period of development and adaptation of tractors and tractor machinery is not yet sufficiently long, as it is now more than a quarter of a century since the mechanical rival of the horse made its appearance. Neither

HORSES versus TRACTORS (*Continued*)—

is the reason to be found in calculations or actual records of the comparative costs of performing specific operations, such as ploughing, by the two methods. The supremacy of the horse in British agriculture is attributable to certain advantages which it possesses over the tractor as the common source of haulage power on the farm.

The chief advantage of the horse is its adaptability to the various operations and conditions of farm work, and in this respect agricultural enterprises offer considerably greater range of variation than do those of urban industry. The power unit—the individual horse—is peculiarly flexible and, therefore, specially adapted to the varying surfaces and gradients on which farm operations have to be performed, or vehicles hauled. Then the size of the team can be adapted to the needs of each operation or job, from large teams, where great tractive force is needed with small man power, to single-horse work as in so many farm duties where human skill and direction are relatively more important than the amount of power in front of the implement.

Another advantage of the horse is its reliability; and, inasmuch as farm work is largely dependent on weather conditions which afford favourable opportunities for their performance, farmers must attach great importance to this consideration. In the case of the tractor the failure or breakdown of one component of the machine involves the temporary disablement of the whole outfit, whereas the failure of one horse in a team may be a comparatively small inconvenience. In practice, despite the increased efficiency and reliability of the modern tractor and its drivers, stoppages are more frequent in tractor than in team management. Horses are undoubtedly simpler to handle and maintain; they are less liable to disablement; and their working condition is apparent, which contrasts with some of the essential mechanism of the tractor, the approaching failure of which may give no warning.

In British agriculture, moreover, there is a large proportion of holdings on which, by reason of their small size or the nature of their husbandry, there are few occasions to make use of an aggregate power so large as that of a tractor. (See Agriculture, Wales.) Indeed, on many grass-land holdings, where horse breeding is one of the sources of income, the power available in this form commonly exceeds the requirements of the farm.

The above discussion serves only to explain why horses are and seem likely to remain the principal source of tractive force in British agriculture. There remains to be discussed the economy of the tractor in a supplementary capacity and, in suitable cases, its partial or almost complete displacement of the horse.

The work of farming is seasonal and irregular in the distribution of its power requirements during the year; moreover, as stated above, progress is very dependent on suitable weather conditions. For example, periods of dry weather during August and September call into action all the forces the farmer can organize to harvest corn crops, clean the stubbles and make all other possible preparations for seeding next year's crops, both autumn- and spring-sown. If the farmers'

HORSES versus TRACTORS (*Continued*)—

tractive forces are merely the horses essential to perform the routine ploughing, carting, hoeing and seeding operations, he will be unable to make very rapid progress, and his autumn cultivations will fall in arrear. Reaping machines require fresh teams every few hours if they are to be maintained in motion all day, and until the corn is cut, stubble breaking and ploughing cannot begin. Additional horses may be kept to deal with such periods of heavy pressure, or a reserve of power may be held in the form of a tractor. The problem is to determine whether horses or a tractor may be the more economical form of this reserve power, and the problem is not an easy one.

According to records published by the Agricultural Economics Research Institute for the year 1927-28, the cost of keeping a farm horse for a year is about £30, and that of operating a tractor for a year in which it worked 848 hours was about £99. Depreciation and repairs amounted to £32 per annum and fuel and oil cost 1s. 7d. per hour worked. There is no doubt that where operations are carried out on a scale large enough to require a reserve of three horses to cope with seasonal demands, a tractor of the same annual expense would be more economical as a reserve of power; the saving which makes the difference in favour of the tractor is in the cost of man power. In ploughing, which is the chief operation in which the tractor is more economical than horse teams, man-labour costs about 2s. 4d. per acre as compared with about 7s. per acre with team ploughing. The saving is thus about 5s. 8d. per acre of ploughing, amounting to £14 3s. 4d. on 50 acres. There would be this area of ploughing to be done in autumn on a farm with 80 acres of arable land: but such a holding would not be large enough to require a reserve force of three horses.

As regards the comparative cost of horse and tractor draught, the Oxford averages are 4·6d. per hour for horse work and 2s. 4d. per hour for tractors. Where the tractor is being worked to its full haulage capacity, equivalent to about six horses, it supplies power at a cost similar to that of horse teams. Therefore, to perform work by tractors at a lower cost than by horse teams it is essential to save on the cost of the necessary man-labour by using wide implements, and, generally to secure a greater output per man per day. Large fields of regular shape, free from wet places and steep gradients, favour tractor work, and under these conditions the tractor tends to become the main haulage force on the farm.

J. R. B.

HUMUS—See Soil Colloids and Humus.

HYDROCYANIC ACID (prussic acid, HCN). A colourless gas of a highly poisonous nature. As usually met with, however, it is sold in 2 or 4 per cent. solution in water. The anhydrous gas should on no account be prepared or used without the most extreme precautions being taken to avoid inhalation. *One breath of the anhydrous gas is fatal.* For fumigation purposes it is prepared by the action of strong sulphuric acid on potassium or sodium cyanide. (See Insecticides and Fungicides; also Glasshouse Crops.) To three out of four people it has a

HYDROCYANIC ACID (*Continued*)—
strong smell of bitter almonds, even in extreme dilution, but curiously enough one person in four is unable to smell it at all. As antidotes, emetics, stimulants, atropine, and injections of sodium sulphide or thiosulphate are recommended, but the poison is so rapid in its action that there is usually no time to obtain and apply these before death supervenes. Certain plants contain cyanic glucosides which are hydrolyzed by water and the digestive juices, yielding small amounts of the acid. Among these the following may be mentioned: *Prunus Laurocerasus*, *P. caroliniana*, *P. serotina*, *Dichapetalum cymosum*, *Phaseolus lunatus*, *Linum usitatissimum*, and *L. catharticum*. Animals of various kinds, especially sheep, have at times succumbed as the result of eating these plants, notably the first, 2 ozs. of the leaves of which is said to be fatal to a sheep in every case. It is noteworthy that the poisonous action depends on the presence of free CN ions; hence potassium cyanide is less poisonous than the acid unless for some reason the solution becomes highly dissociated, as when it comes in contact with the dilute hydrochloric acid of the gastric juice. Applied locally, the solution acts as an analgesic, but care must be taken as it passes through the skin to the blood stream. Medicinally, it is useful in very minute doses in cases of gastric irritation, whatever the causes, and as a vermifuge.

HYDROGEN (atomic weight 1·007, atomic number 1)—The lightest gas known. A chemical element (*q.v.*). One of the chief constituents of water and all organic substances.

HYDROLYSIS—The splitting up of a chemical compound by the addition on to it of the elements of water, *e.g.*, ethyl ester, may be split into alcohol and acetic acid thus:

$$\begin{array}{rl} C_2H_5COO & C_2H_5 \\ H & OH \end{array}$$

the elements of water being added in the manner indicated. This reaction proceeds to some extent with water alone, but is aided by dilute acids or alkalies. The actual splitting is due to the establishment of an equilibrium between the two systems indicated by the equation

$$\text{Ester} + \text{free } H' \text{ and } OH' \text{ ions} \rightleftharpoons \text{alcohol} + \text{acetic acid.}$$

This renders the reason for the catalytic action of acids and alkalies clear, since they greatly increase the number of free H′ and OH′ ions in the solution, thus accelerating both sides of the reaction, bringing it more rapidly to the equilibrium point. (See Enzymes and Fermentation.)

HYDROMETER—An instrument for the rapid determination of the specific gravity of liquids. The history of such articles goes back a very long way, and they are said to have been used by Archimedes. The principle on which all types work is the same, namely, that if a body is floating on the surface of a liquid, then the weight of a volume

HYDROMETER (*Continued*)—

of the liquid equal in bulk to that of the immersed part is equal to the weight of the body. Hence, if the specific gravity of the liquid becomes less, the body will sink in more deeply, and if the part of the body which normally protrudes from the liquid is very thin, a very small reduction in the specific gravity will cause the immersion of a considerably greater portion of this thin stem, thus facilitating the measurement of very small changes of density in the liquid. (For the distinction between density and specific gravity see Specific Gravity; it is here immaterial.)

Hydrometers usually consist of a bulb of brass or glass which is weighted so that it floats below the surface of the liquid with which it is used, and this is surmounted by a thin stem which floats partly above and partly in the liquid. The usual type used in laboratories consists of a glass bulb float with a lower one containing mercury or lead shot to weight it, so that the thin tubular stem pierces the liquid surface. This stem contains a paper scale on which specific gravities are marked. These instruments are inexpensive, and it saves much trouble to keep a series suitable to all measurements to be made. The specific gravities of liquids vary with temperature, and the volume of the float bulb varies with both temperature and pressure, and what correction is necessary on these accounts is usually made from tables; but there is another source of error which, especially in the case of water and aqueous solutions, is often of greater moment, and cannot easily be corrected for—namely, the depression caused by the surface tension of the liquid where it wets the stem; this varies greatly with the slightest impurity in the liquid and sets a definite limit to the accuracy of hydrometers. A hydrometer of the above type should carry a fiducial mark to guard against a possible displacement of the paper scale in the stem.

A few older types are still in use, and should be mentioned. Sykes' hydrometer, used for alcohol-water mixtures, has a hollow brass float, and is supplied with a set of weights so arranged that the reading in Sykes degrees = weight on bulb + scale reading on stem. One Sykes degree = an interval of approximately 0·002 in specific gravity. Twaddell's hydrometer is a glass one, so arranged that specific gravity $= 1 + \frac{\text{Twaddell degrees}}{200}$; thus 1° Tw. = 0·005 specific gravity interval, and is used for milk and other liquids having a density greater than unity. Zero in Baumé's hydrometer is the specific gravity of water at 10° Réaumur (see Thermometer); 15° Bé. that of a 15 per cent. salt solution at the same temperature. Specific gravity (15° C.) $= \frac{144{\cdot}3}{144{\cdot}3 - \text{Baumé degrees}}$.

A drawback of all the types described is the variable immersion, which may be, but often is not, corrected for in the scale. In Nicholson's constant displacement hydrometer, which is of plated brass, the hydrometer is sunk to a definite mark on the thin stem by weights placed in a pan on the end of the stem; thus we have, if H is the weight

HYDROMETER (*Continued*)—

of the hydrometer, and $W_{aq.}$ the weight required to sink it to the mark in water at 15° C., and $W_{liq.}$ the weight to sink it to the mark in the liquid at the same temperature—specific gravity (15° C.) $=\frac{H+W_{liq.}}{H+W_{aq.}}$.

HYGROMETER—An instrument for measuring the absolute or relative humidity of the air. The former of these is the actual amount of water vapour in the air sample in grams per cubic metre; the latter the humidity under the conditions obtaining expressed as a percentage of the saturation humidity under those conditions. The only really accurate hygrometer is the chemical hygrometer, in which a known quantity of the air is passed over calcium chloride or phosphoric anhydride, which absorbs the water vapour from it, the weight of the latter being directly determined. For practical purposes, however, this is most cumbersome, and numerous physical instruments have been devised which give the absolute or relative humidity with an error in the best types of not more than about 1 per cent. The most usual type employed on farms and in small meteorological stations is Mason's wet and dry bulb hygrometer, consisting of two thermometers mounted side by side, the bulb of one being kept moist by a piece of muslin tied round it, the lower end of which dips into a reservoir of distilled water placed immediately below it. The theory of this type was worked out by Apjohn as early as 1834 on the assumption that the cooling of the layer of air in contact with the wet bulb at any moment supplies the whole of the heat required to maintain the evaporation, and itself becomes saturated in the process. He obtained the formula

$$f=F_2-(\theta_1-\theta_2)\frac{sH}{L\rho}$$

in which f is the actual aqueous tension in the air, F_2 the maximum, *i.e.*, saturation pressure at the temperature θ_2 of the wet bulb, θ_1 the dry bulb temperature, s the specific heat of air, H the barometric pressure, L the latent heat of vaporization at θ_2, and ρ the relative density of water vapour. In practice the assumptions are not justified, and it is usual to place the hygrometer inside a Stevenson screen and use Glaisher's hygrometric tables. Even then the accuracy is less than in similar instruments of the Assmann type, in which air is drawn over the thermometers at a speed of not less than 3 metres per second used with the specially computed "Aspirations-Psychrometer-Tafeln," published by the Royal Prussian Meteorological Institute (F. Vieweg, Braunschweig, 1914). In parts of the world where the temperature is below freezing point for the greater part of the year, and in aeronautical work, the old hair hygrometer has many advantages, but the precautions necessary to secure accuracy are numerous, and such hygrometers are useless in very dry places. A full discussion of these and many other types of instruments for measuring humidity is to be found in the full account of a discussion on the subject published as an addendum to the *Proc. Physical Soc.*, London, vol. xxxviii., part ii.,

HYGROMETER (*Continued*)—

1922, which may be supplemented by the information contained in section v. of chapter v. of Preston's "Theory of Heat" (Macmillan).

IMPROVEMENTS AND OTHER RIGHTS, COMPENSATION FOR, PARTICULARLY RELATING TO AGRICULTURAL TENANTS—

Fixtures—For many centuries it was a rule of law that anything annexed to land, known as a fixture, appertained to and formed part of the land, the maxim being, "quicquid plantatur solo, solo cedit." To constitute a fixture, the article must be annexed to the land either by displacement of the soil to receive it, or annexation to some article already being, or forming part of, a fixture; consequently, a Dutch barn is not a fixture if, being placed on bricks, it has sunk into the ground merely by its own weight. The Common Law rule as to removal of fixtures was later relaxed to enable a tenant to remove fixtures put up by himself for the purposes of trade or ornament, provided that such removal was effected during the continuance of the tenancy. This right of removal, however, did not extend to fixtures erected for agricultural purposes only. A nurseryman might remove his greenhouses used for trade, and also trees planted for sale, but could not remove orchard trees.

The Landlord and Tenant Act, 1851, section 3, gave some relief in this respect by providing that where any building, engine, or machinery shall, after the passing of that Act, be erected by a tenant, with the consent in writing of his landlord, and not in pursuance of any obligation in that behalf, such erection shall be the property of the tenant and be removable by him provided that no injury be done to the holding by such removal, and subject to his giving to his landlord one month's notice of his intention to make such removal, and to the right of the landlord to elect to purchase such fixtures intended to be removed at a value to be ascertained by two referees or their umpire.

The right to the removal of fixtures given by the Landlord and Tenant Act, 1851, was modified and extended by the Agricultural Holdings Act, 1875, with respect to fixtures and buildings on holdings to which such Act applied. Written consent of the landlord to erect the fixture was no longer necessary to enable the tenant to claim such right. The tenant had to pay all rent owing and satisfy any other obligation to his landlord before effecting the removal; in making the removal he was prohibited from doing any avoidable damage; immediately after the removal he was obliged to make good all damage occasioned thereby, notice of intention to make such removal was required as before, and the landlord had his previous right of acquiring the fixture by valuation. The Agricultural Holdings Act, 1883, which repealed the Act of 1875, reserved any right in respect of fixtures acquired by such Act, and practically re-enacted these provisions, save that it permitted the removal to be before or within a reasonable time after the termination of the tenancy.

Although the harshness of the Common Law rule preventing the removal of fixtures which had been erected by a tenant was considerably relaxed by legislation during the latter part of the nineteenth

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

century with regard to fixtures which had been erected by him, it was not until the passing of the Agricultural Holdings Act, 1900, that provision was made enabling a tenant to remove fixtures which he should acquire subsequent to the passing of that Act. The right of a tenant to remove any engine, machinery, fencing, or other fixture affixed to a holding is now contained in Section 22 of the Agricultural Holdings Act, 1923. It must, however, be borne in mind that the tenant may be precluded of this right by express agreement with his landlord to this effect.

Improvements—The old practice of open-field cultivation and common of pasture prevalent throughout the kingdom for many centuries did not encourage development of the resources of the soil. It was not until lands were enclosed that improvements in general husbandry to any great extent were effected. Before the year 1876 the tenant of an agricultural holding was not entitled to compensation for any improvements made by him to the holding, unless he could prove that his landlord had agreed to allow such compensation, or that he was entitled thereto in accordance with the custom of the country in which the holding was situate. The burden was upon the person alleging the custom to prove its existence; it could not be established in a court of law unless it was reasonable and had been for some considerable length of time in prevalent usage in the district. Even if such custom existed, the terms of the tenancy might prevent its application by expressly or impliedly excluding its operation, though, even at the present day, a custom of the country may be introduced to supplement the terms of a tenancy, provided that such custom is not inconsistent thereto and does not refer to compensation for any improvement for which compensation is now claimable under the provisions of the Agricultural Holdings Acts.

Although the Common Law—that is, law applicable to the whole realm laid down by judges in the King's Courts—did not allow compensation to a tenant for any improvement made by him to the land, yet, in the absence of local custom or express stipulation with his landlord, it implied an undertaking by him to cultivate the land in a husbandlike manner, and failure in this respect would give his landlord a right of action against him. On the other hand, the Common Law did not imply any warranty by the landlord that the land let was fit for cultivation or free from noxious weeds. In the absence of custom or agreement it is not sufficient for a tenant to maintain land in the condition in which he took it if it was below proper condition at the commencement of the tenancy, but he will not be under liability to his landlord if, owing to the short duration of his tenancy, he has not had time to get the land in proper condition; conversely, he is not obliged to keep land in better than proper condition.

The first statutory enactment granting to agricultural tenants the right to claim compensation for improvements was the Agricultural Holdings Act, 1875, which came into operation in February, 1876. This Act related to holdings which were either wholly agricultural or wholly pastoral, or in part agricultural and as to the residue pastoral,

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

but excluded all holdings less than 2 acres in extent. The Act could not be described as a great boon to the agriculturalist because, not only was it not retrospective, but it was also entirely permissible. Tenancies current at the commencement of the Act did not come within its provisions except such as were from year to year or at will, and not even these if either the landlord or the tenant gave notice to the other within a certain specified time desiring the existing contract of tenancy to remain unaffected by the Act. Tenancies created after the passing of the Act were subject to its provisions only in so far as there was no express agreement between the parties to the contrary, and, in fact, in the vast majority of cases landlords took care that, both as to existing tenancies which in the absence of notice by either party would become subject to the provisions of the Act, and in the creation of new tenancies, the provisions of the Act were excluded.

The Act of 1875 dealt only with certain improvements effected after its commencement. These improvements were divided into three classes according to whether the tenant had to obtain the written consent of his landlord before executing the improvement, or had to serve notice upon him of his intention to effect the improvement, or could effect the improvement without previous consent or notice.

The first class comprised those improvements which required the written consent of the landlord, and are all of a more or less permanent nature. Compensation in respect of these improvements was calculated upon the sum expended by the tenant, less a deduction of a proportionate part thereof in respect of each year the tenancy continued after the outlay was made, and a further deduction in respect of any sum reasonably necessary to be expended in putting the improvement into tenantable repair or condition. Compensation was not payable if the improvement was exhausted, and the Act provided that no improvement in this class should be deemed to continue unexhausted at the end of twenty years following the year of tenancy in which the outlay was made.

The second class comprised those improvements where notice had to be given before execution of the work, in the manner specified in the Act. An improvement in this class was deemed exhausted, in any case, at the end of seven years after the year of tenancy in which the outlay was made thereon. The tenant could not claim compensation if the work was executed after he had given or received notice to quit, unless his landlord had consented in writing to the work being done. Consequently, a landlord objecting to the work being carried out could effectually prevent it by serving notice to quit. The compensation payable for improvements effected under this class was calculated in similar manner to that for improvements under the first class.

The third class comprised those improvements which did not require previous consent of, or notice to, the landlord. They consisted of application to the land of purchased manures and the consumption on the holding by cattle, sheep, or pigs of cake or other feeding stuff not produced on the holding. The value of these improvements was deemed exhausted, in any case, in two years after the year of tenancy in which

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

they were effected, and compensation was not payable if a crop of corn, potatoes, hay, or seed, or any other exhausting crop, had been subsequently taken from the portion of the holding on which the improvement was executed. Any outlay on these improvements during the last year of the tenancy in excess of the average outlay of the last three preceding years was not to be taken into account for ascertaining the amount of compensation, and the value of the manure which would have been produced by hay, straw, roots, or green crops sold off the holding during the last two years was to be deducted, except as far as a proper return of manure should have been made in respect of such produce sold off. (See Feeding Stuffs, Manurial Values of; Fertilizers, Residual Value of.)

The Agricultural Holdings Act, 1883, which repealed the Act of 1875, may justly be denominated the Tenant's Charter. It was partly retrospective and to a great extent compulsory. All the improvements specified in the Act of 1875 were included in this Act, but the method of ascertaining the amount payable as compensation was altered. The provisions relating to improvements contained in the Act were mainly founded upon the report of a Royal Commission. Although such provisions have been partially amended and twice repealed for the purposes of consolidation, they form the basis of the law relating to compensation for improvements at the present day, as contained in the provisions of the Agricultural Holdings Act, 1923.

The Act of 1883 applied to Agricultural Holdings, although of less extent than 2 acres, and also to holdings in whole or in part cultivated as a market garden, but expressly excluded any holding let to a tenant during his continuance in any office, appointment, or employment held under his landlord, and lettings of under one year in duration did not come within the operation of the Act. The amount of compensation payable was no longer calculated upon the actual sums expended by the tenant with deductions therefrom and with time limits when improvements should be deemed exhausted, but upon the value of the improvement to an incoming tenant. A proviso stated that in estimating the value of any improvement there should not be taken into account as part of the improvement made by the tenant what is justly due to the inherent capabilities of the soil. It would be extremely difficult, if not impossible, to estimate what is justly due to the inherent capabilities of the soil; indeed, in view of the great improvement in the condition of land in general effected during the past two or three centuries through improved husbandry, one is led to doubt the existence of such inherent capabilities. The term does not appear to have been defined in any court of law, and the proviso was excluded in the consolidating Act of 1908.

The Act of 1883 again divided improvements into three classes for the purpose of requiring the tenant to obtain the written consent of his landlord, or to serve notice upon him, before effecting certain improvements, to entitle him to compensation therefor, but there were no time limits when improvements should be deemed exhausted as in the previous Act.

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

It was necessary to obtain the landlord's consent for all improvements which previously required his consent by the Act of 1875, except for that of drainage. The landlord in giving his consent might make it conditional upon certain terms as to compensation, or otherwise, but if consent was given unconditionally the tenant, on quitting the holding, would be entitled to claim the value of the improvement to an incoming tenant. Drainage was classified separately under Part II. of the Schedule as the only improvement where the tenant had to give notice in writing of his intention to execute the work. Such notice had to be given within the times specified in the Act, and had to state therein the manner in which he proposed to do the work. The landlord might agree terms as to compensation, or otherwise, with the tenant; or, provided that the tenant did not withdraw his notice, he might undertake to execute the work in any reasonable and proper manner he should think fit, and add to the rent 5 per cent. on the outlay, or such annual sum for a period of twenty-five years as would repay such outlay with interest at 3 per cent. In the event of the parties failing to come to any agreement, or of the landlord failing to comply with his undertaking within a reasonable time, the tenant might execute the improvement himself and be entitled to compensation under the Act.

Improvements which the tenant might execute without previous consent were set out in Part III. of the Schedule: these comprised all the improvements specified in the former Act where consent in writing of the landlord was not required. It will be recollected that with the exception of two improvements, *e.g.*, the application to land of purchased manure and the consumption on the holding of feeding stuffs not produced thereon, where written consent was not required, notice had previously to be given to the landlord of intention to execute the improvements, and no compensation was payable for any such improvements effected after notice to quit had been given, unless the landlord had given his consent in writing to the execution of the work. As a consequence, a tenant would naturally hesitate before giving notice of intention to execute an improvement in fear lest his landlord would object to such improvement and give him notice to quit. This Act afforded considerable encouragement to the tenant to execute these improvements, by no longer requiring him to give such notice except as to such improvements, where notice was previously required, which were commenced during the last year of the tenancy or after notice to quit had been given; in such latter cases compensation was not payable unless notice was given, and the landlord had consented, or failed to object, to execution of the work. Moreover, no agreement between the parties, executed after the commencement of the Act, could deprive the tenant of his claim to compensation, but an agreement in writing providing for fair and reasonable compensation, having regard to the circumstances existing at the time of making such agreement, would substitute compensation under the Act.

In addition to compensation for improvements made by a tenant, compensation was allowed for improvements purchased, with the con-

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

sent of the landlord, from an outgoing tenant. Upon a tenant giving notice of his intention to claim compensation, in manner provided by the Act, the landlord was entitled to counterclaim in respect of any waste or breach of agreement committed within four years of the determination of the tenancy. All matters under the Act were to be referred to a referee, or two referees and, where necessary, an umpire; consequently, where an agreement had provided for compensation to a tenant for such improvements as he was entitled to be compensated for in spite of any agreement to the contrary, it was for them to decide whether the compensation provided by such agreement was fair and reasonable, from whose decision there was no appeal if their award was under £100.

The Market Gardeners Compensation Act, 1895, extended and amended the provisions of the Act of 1883 as to compensation for improvements so far as they related to market gardens. A few alterations and additions were made to the Improvements specified in the Acts of 1883 and 1895 by the Agricultural Holdings Act, 1900. One improvement, that of boning of land with undissolved bones, has been omitted from this and the subsequent Acts. The reason for this omission has been stated by some writers to have been because this improvement was considered comprehended in that of the application to land of purchased manure; it is quite probable, however, that by this time there was no necessity to include this improvement, for as soon as it was discovered that a soluble form of phosphate could be obtained by treating bones, and other forms of phosphatic material, with sulphuric acid, the use of a very soluble form of manure ceased to have any commercial advantage to the farmer.

The Agricultural Holdings Act, 1908, consolidated the law relating to compensation for improvements by repealing the before-mentioned Acts of 1883, 1895, and 1900 (also an Act of 1906 which had not come into operation), and re-enacting their provisions on this subject. Amendments were made by subsequent Statutes to the consolidating Act of 1908, and the law was again consolidated by the Agricultural Holdings Act, 1923, which Act is the present authority on this subject.

All improvements for which a tenant is entitled to claim compensation are now set out in the Agricultural Holdings Act, 1923. Improvements to which the consent of the landlord is required are contained in Part I. of the First Schedule, and are as follows:

1. *Erection, alteration, or enlargement of buildings.*
2. *Formation of silos.*
3. *Laying down of permanent pasture.*
4. *Making and planting of osier beds.*
5. *Making of water meadows or works of irrigation.*
6. *Making of gardens.*
7. *Making or improvement of roads or bridges.*
8. *Making or improvement of watercourses, ponds, wells, or reservoirs, or of works for the application of water power or for supply of water for agricultural or domestic purposes.*
9. *Making or removal of permanent fences.*

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

10. *Planting of hops.*
11. *Planting of orchards or fruit trees.*
12. *Protecting young fruit trees.*
13. *Reclaiming of waste land.*
14. *Warping or weiring of land.*
15. *Embankments and sluices against floods.*
16. *Erection of wirework in hop gardens.*
17. *Provision of permanent sheep-dipping accommodation.*
18. *In the case of arable land the removal of bracken, gorse, tree roots, boulders, or other like obstructions to cultivation.*
19. *Drainage* is the only improvement contained in Part II. of this Schedule, where notice is required before effecting such improvement. The former provisions enabling the landlord to undertake the work and charge the tenant on the outlay are re-enacted.

Improvements which may be effected without consent or notice are contained in Part III. of this Schedule, and are as follows:

20. *Chalking of land.*
21. *Clay-burning.*
22. *Claying of land or spreading blaes upon land.*
23. *Liming of land.*
24. *Marling of land.*
25. *Application to land of purchased artificial or other purchased manure.*
26. *Consumption on the holding by cattle, sheep, or pigs, or by horses other than those regularly employed on the holding, of corn, cake, or other feeding stuff not produced on the holding.*
27. *Consumption on the holding by cattle, sheep, or pigs, or by horses other than those regularly employed on the holding, of corn proved by satisfactory evidence to have been produced and consumed on the holding.*
28. *Laying down temporary pasture with clover, grass, lucerne, sainfoin, or other seeds, sown more than two years prior to the termination of the tenancy in so far as the value of the temporary pasture on the holding at the time of quitting exceeds the value of the temporary pasture on the holding at the commencement of the tenancy for which the tenant did not pay compensation.*
29. *Repairs to buildings, being buildings necessary for the proper cultivation or working of the holding, other than repairs which the tenant is himself under an obligation to execute: Provided that the tenant, before beginning to execute any such repairs, shall give to the landlord notice in writing of his intention, together with particulars of such repairs, and shall not execute the repairs unless the landlord fails to execute them within a reasonable time after receiving such notice.*

Improvements specially applicable to market gardens which may be executed without previous consent or notice are contained in the Third Schedule, and are as follows:

1. *Planting of standard or fruit trees permanently set out.*
2. *Planting of fruit bushes permanently set out.*
3. *Planting of strawberry plants.*

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

4. *Planting of asparagus, rhubarb, and other vegetable crops which continue productive for two years or more.*

5. *Erection or enlargement of buildings for the purpose of the trade or business of a market gardener.*

With regard to improvements contained in Part I. of the First Schedule to the Act of 1923, where the consent of the landlord is required, as previously related, the landlord may make terms as to compensation or otherwise; it has been held, however, that a landlord cannot impose as a condition to his consent that no compensation shall be paid (Mears *v.* Callender, 1901). Compensation is therefore payable in respect of all the improvements specified above, either according to agreement or in manner provided by the Act, provided that consent has been obtained, or notice given, where required, and the necessary procedure as to giving notice claiming compensation, as laid down in the Act, has been complied with. Conflicting decisions, however, arose in the Courts as to whether a tenant was entitled to compensation for an improvement which he was required to make under the terms of his tenancy agreement, it being argued that as he had agreed to execute the improvement, he had already received a benefit by reduction of rent or otherwise. Section 1 of the Agricultural Holdings Act, 1923, now provides that as to a contract of tenancy made on or after January 1, 1921, compensation shall be payable in respect of improvements, whether such were required by the terms of the tenancy or not, and the case of Huckell *v.* Sainty, decided in 1923, laid down that no compensation was payable for an improvement required by the terms of the tenancy where the tenancy agreement was entered into before 1921.

Not only may a tenant claim compensation for any of the improvements specified in the First and Third Schedules to the Act of 1923, but he may claim compensation for the increase in value of the holding effected during his tenancy by the continuous adoption of a standard or system of farming which has been more beneficial to the holding than the standard or system required by the contract of tenancy. The Agricultural Holdings Act, 1908, empowered a tenant to practise any system of cropping of the arable land and disposal of the produce of the holding notwithstanding any custom of the country or terms of his tenancy to the contrary. This, however, does not apply to the last year of the tenancy or after notice to quit, and the tenant's rights during such period are governed by the tenancy agreement. In the exercise of this power he is obliged to make suitable and adequate provision to protect the holding from injury or deterioration; which, in the case of disposal of produce, consists in the return to the holding of the full equivalent manurial value of all crops sold off or removed in contravention of the custom or terms of the holding. In the event of the tenant exercising this power in such a manner as to injure or deteriorate the holding, or to be likely so to do, the landlord may, apart from any other remedy open to him, should the case so require, obtain an injunction restraining the exercise of this power, as well as damages for any such injury or deterioration.

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

Compensation for Increased Standard of Cultivation—Compensation for the improved value of the holding to an incoming tenant by a continuous adoption of a special standard or system of cropping more beneficial than that required by the contract of tenancy was first provided for by the Agriculture Act, 1920, upon notice given as therein contained, and this provision is re-enacted by Section 9 of the Agricultural Holdings Act, 1923. Conversely, a landlord is enabled to claim compensation on the termination of the tenancy, apart from any special provisions contained in the tenancy agreement, for deterioration of the holding during the tenancy by the failure of his tenant to cultivate the holding according to the rules of good husbandry or the terms of the tenancy agreement.

Compensation in respect of the increased value of a holding is only payable for such increase in value as shall have been effected after a record of the condition of the holding has been made, as provided for by the Act; a landlord, however, is entitled to compensation for deterioration of the holding, although no such record of the condition of the holding has been made, provided that he proves to the satisfaction of the Arbitrator that such deterioration has taken place. In determining the amount of compensation payable to an outgoing tenant for increased value as aforesaid, allowance has to be made for compensation payable to the tenant for any improvement specified in the Act which has caused or contributed to the benefit. As during the last year of a tenancy a tenant is still obliged to comply with any condition of his tenancy agreement as to cultivation, the increased value of the holding to an incoming tenant by the continuous adoption of a system of cropping, which is the basis on which the amount of compensation is calculated, may be negligible.

Ground Game—In view of the many inalienable privileges enjoyed by the agricultural tenant at the present day, it is difficult to realize that these privileges are practically all of comparatively recent introduction. Only half a century ago a landlord could preclude his tenant from taking rabbits from off the land let to him. This appears to have been done by many large estate owners, and tenants witnessed their crops being eaten up without any redress. An Act of 1848, enabling persons having a right to kill hares to do so without being required to take out a game certificate, shows that much damage was being done, the preamble to the Act stating, " It has been found that much damage has been and is continually done by hares to the produce of enclosed lands, and that great losses have thereby accrued, and do accrue, to the occupiers of such lands." An Act of 1860 extended the exemption of taking out a game licence to the killing of rabbits. It was not, however, until the Ground Game Act, 1880, came into operation in September of that year that occupiers of land had, as incident to and inseparable to their occupation, together with any other person entitled thereto, the right to kill and take rabbits and hares. The right given by this Act is limited to the occupier and one person authorized by him in writing in that behalf, such person being either a member

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

of his household resident on the land, a person in his service on the land, or a person *bonâ fide* employed by him for reward in the taking and destruction of hares and rabbits. All agreements made subsequent to the passing of the Act in contravention of the right of the occupier to destroy hares and rabbits as given by the Act are void, but the Act did not affect leases then existing where the right to kill and take hares and rabbits, therein referred to as ground game, was vested in some other person. A tenant from year to year or at will not then possessing the right to kill ground game became entitled thereto under the provisions of the Act at the time when his tenancy would by law be determinable if notice to determine such tenancy was given at the date of the passing of the Act. The rights conferred by the Act are expressed to be granted to occupiers. A tenant who sublets land no longer retains the right to kill and take ground game therefrom. Occupiers for the purpose of grazing sheep, cattle, or horses for a period of nine months or less are, however, expressly excluded from the rights conferred by the Act.

Compensation for Damage by Game—Where land is now let with shooting rights reserved, the occupier of the land has still to comply with the provisions of the Ground Game Act, 1880, to enable him to take and kill such ground game, but he may claim compensation if his crops have been considerably damaged by game, other than ground game. This right to compensation was first given by the Agricultural Holdings Act, 1908, repealing a similar provision in the Act of 1906, which did not come into operation, and such right is now contained in Section 11 of the Agricultural Holdings Act, 1923. This section, which defines game as meaning deer, pheasants, partridges, grouse, and black game, provides that where a tenant of a holding has sustained damage to his crops from game, the right to kill and take which is vested neither in him nor in anyone claiming under him other than the landlord, and which the tenant has not permission in writing to kill, he shall be entitled to compensation from his landlord, as shall be determined by arbitration, if such damage exceeds in amount the sum of 1s. per acre of the area over which the damage extends. Notice in writing must be given to the landlord as soon as may be after the damage is first observed by the tenant, and the landlord must be given a reasonable opportunity to inspect the damage:

(*a*) In the case of damage to a growing crop, before the crop is begun to be reaped, raised, or consumed, and
(*b*) in the case of damage to a crop reaped or raised, before the crop is begun to be removed from the land.

Notice of the claim has to be given as provided by the Act, and deductions from such compensation are made in respect of tenancies commenced before 1909 where the landlord proves that in fixing the rent allowance had been made for such damage or compensation was payable by him under the agreement.

Although an owner of land has no redress for injury done to crops

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—
on his land by game bred on neighbouring land, provided that such game or their progeny were not brought on to such neighbouring land, yet he may be liable to compensate his tenant for damage caused by game coming from his neighbour's land, even during close season (Thomson *v.* Galloway, 1919).

Termination of Tenancy—The holding of land for an uncertain duration was at one time by no means uncommon, as, for instance, during life, or the lifetime of another. A tenant whose tenancy became thus unexpectedly determined was entitled to enter upon the land to reap what he had sown—that is, to take such growing crops as are annually produced by the cultivator growing upon the land when his tenancy determined, but not such crops as are not annually produced by cultivation, such as apples. This was known as a right to "emblements." A tenant had no right to emblements if his tenancy was determined by his own fault or his own act.

The Landlord and Tenant Act, 1851, recited that it was expedient to amend the law to prevent or lessen the evils of the right to emblements, and the loss and injury arising therefrom, and provided that where the lease or tenancy of any farm or lands held by a tenant at rack rent should determine by the death or cesser of the estate of any landlord entitled for his life or for any other uncertain interest, instead of claim to emblements, the tenant should continue in occupation until the expiration of the then current year of his tenancy. The Agricultural Holdings Act, 1875, provided that where half a year's notice expiring with the year of tenancy was previously required, a year's notice should thereafter be necessary; this, however, did not prevent the parties from stipulating for any other period of notice.

Some further protection was given to the agricultural tenant by the Conveyancing Act, 1881, which entitled mortgagors to grant agricultural leases for any term not exceeding twenty-one years, which leases would be valid against their mortgagees; this power only related to mortgages created after the passing of the Act, and only applied if a contrary intention was not expressed in the mortgage deed, and, in fact, many mortgages created at the present day contain a declaration against leasing. The Tenants Compensation Act, 1890, protected the tenant as against his landlord's mortgagee by granting him the same right to compensation for improvements as he would have been entitled to as against his landlord and requiring the mortgagee to give six months' notice in writing of his intention to deprive him of possession. A tenant occupying a holding under a contract of tenancy with a mortgagor, which is not binding on the mortgagee, may still be deprived of possession six months after notice given by the mortgagee to that effect, but any notice to quit a holding given by either landlord or tenant after 1920 is, subject to certain exceptions, invalid if it purports to terminate the tenancy before the expiration of twelve months after the end of the then current year of tenancy. Moreover, any contract entered into for the sale of a holding now invalidates an unexpired notice to quit given by the vendor, unless the tenant, prior to the date

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

of such contract of sale, by writing, has agreed that such notice shall be valid; and a tenancy held under a lease of two years or upwards granted after 1920 continues at the expiration of the lease as a tenancy from year to year unless either party terminates the tenancy by written notice given not less than one year nor more than two years before the date fixed for the expiration of the term.

Compensation for Disturbance—The recent introduction of Compensation for Disturbance has done much to afford security of tenure to the tenant who cultivates his holding in a husbandlike manner, and his interest in the holding has been still further protected by provision for arbitration as to rent. In discussing compensation for disturbance, it must be borne in mind that the Agricultural Holdings Act does not apply to tenancies created for less duration than a year, this subject therefore does not apply to letting of grass keeping for the summer months. Compensation for disturbance was first provided for by the Agricultural Holdings Act, 1908, but this only applied where the tenant had quitted the holding as a result of his landlord having given him notice to quit, or refused to grant a renewal of the tenancy, without good and sufficient cause and for reasons inconsistent with good estate management, or as a result of his landlord demanding an increase of rent by reason of the increase in value of the holding due to improvements effected by the tenant at his own cost.

A new form of compensation for disturbance was introduced by the Agriculture Act, 1920, and is now contained in Section 12 of the Agricultural Holdings Act, 1923. This form of compensation applies to all holdings within the meaning of the Act where notice to quit is given subsequent to May 20, 1920, except as to land forming part of a park, garden, or pleasure ground, attached to and usually occupied with the mansion house, or any land adjoining the mansion house which is required for its protection or amenity; in such latter cases the old form of compensation for disturbance, introduced in 1908, is still applicable. The new form of compensation does not apply to leases created before 1921 as no notice to quit is required to terminate them.

Whilst a claim to compensation for disturbance was formerly dependent upon the landlord terminating or refusing to renew the tenancy, without good and sufficient cause and for reasons inconsistent with good estate management, the general principle, under the new form, is that of recompense to the tenant who has been obliged to quit the holding through no fault on his part, and the convenience of the landlord is not a matter for consideration. There are certain exceptions to this principle where no compensation is payable, as in the case of land owned by certain public bodies and statutory undertakings who require the land for the purpose for which it was acquired by them. An important exception is that of a letting by a landlord who at the creation of the tenancy had been in occupation of the holding for a period of not less than twelve months. In such a case no compensation for disturbance is payable if there is a written contract of tenancy stating that if the landlord desires to resume his occupation before the

IMPROVEMENTS AND OTHER RIGHTS (*Continued*)—

expiration of a certain term, not exceeding seven years, he shall be entitled to give notice to quit without becoming liable to pay such compensation, and the landlord has given notice in accordance with such terms.

The section sets out certain grounds upon which the tenant is not entitled to this compensation, provided that in notices to quit given after 1920 one or more of such grounds are specified therein. Briefly these are, where the tenant—

(*a*) Had failed to cultivate the holding according to the rules of good husbandry.

(*b*) Had failed, within a reasonable time, to comply with a written notice requiring payment of rent or the remedy of a breach of a term of the tenancy.

(*c*) Had materially prejudiced the interests of his landlord by committing a breach of his agreement not capable of being remedied.

(*d*) Had become bankrupt or compounded with his creditors.

(*e*) Had failed to comply with a demand for arbitration as to rent.

(*f*) Had refused to comply with a demand requiring him to execute, at the expense of his landlord, an agreement setting out the terms of the tenancy.

Also, compensation is not payable if the tenant has unreasonably refused or failed to accept an offer by the landlord to withdraw the notice to quit. A tenant must establish that he has sustained some loss directly attributable to the quitting of the holding. If he holds another holding the amount of compensation is reduced by such an amount as represents the reduction of the loss by reason of his continuance in possession of such other holding, but, subject to this, he is entitled as a minimum to a sum equivalent to a year's rent as compensation, although his loss may be only a nominal one, and if he can establish his loss at greater than a year's rent, he may recover his whole loss and expenses to a maximum amount equal to two years' rent of the holding.

The personal representatives of a tenant are not entitled to compensation for disturbance if notice to quit is given within three months after the death of the tenant.

Arbitration as to Rent—As shown above in clause (*e*), a landlord may demand arbitration on the amount of rent to be paid, and, if the tenant refuses to arbitrate, the landlord may give notice to quit without being liable to pay compensation for disturbance. On the other hand, a tenant also may demand such arbitration, and if the landlord refuses to arbitrate the tenant may give notice to quit, stating in such notice that it is given on account of such refusal, and he is then entitled to claim compensation for disturbance in the same manner as if the tenancy had been terminated by notice to quit given by the landlord. Arbitration as to rent cannot be claimed by either party so as to take effect within two years of the commencement of the tenancy, or, where there has been a previous arbitration as to rent, within two years of the date on which the previous increase or reduction of the rent took effect.

J. D. M.

INDIA, Agriculture of—See Agriculture.

INDIAN SUGAR-CORN—See Market Gardening.

INSECTICIDES AND FUNGICIDES—Insect pests and fungus diseases of cultivated crops are annually responsible for very great losses throughout the world. A conservative estimate places the losses in Great Britain due to insects only at not less than £6,000,000 per annum, and this takes no account of damage to livestock, forest trees, timber, and stored products of all kinds. No reliable estimates can be given of the extent of the losses caused by fungi, but probably three times the above figure would not cover the damage done by pests of all kinds. In attempting to reduce such losses, mechanical, cultural, and biological methods are all of great importance, but there is no doubt that we must look to the employment of chemicals to destroy or prevent the attacks of insect and fungus pests as the chief means for control at present at our disposal.

Insecticides and fungicides include liquids for spraying, finely powdered solids for use as dusts, and gases for fumigation. To be of practical value they must be easily prepared, have high toxicity to the pests to be controlled, and must not cause serious damage to the crops or products to which they are applied; if possible, also, they should not be poisonous to man and the higher animals.

Preparations for use as *spray fluids* must be easily miscible with water, *i.e.*, they must be soluble or remain readily suspended or be easily emulsified. They must also have good spreading and wetting properties, in order that the liquid may cover as completely as possible the surface on to which it is sprayed and spread into minute holes and crevices, thus coming into close contact both with the plant surface and insects or fungi which may be present. Before a liquid can spread, it must wet the surface, and to increase the wetting and spreading power of spray fluids, various substances, of which soap is the most important, are commonly added. The effect is to reduce the surface tension of the liquid, though this may not be the only factor concerned with the increase of wetting power (Woodman, *J. Pom. and Hort. Sci.*, iv., 38, 1924; *J. Soc. Chem. Ind.*, xlix., 93T, 1930). A further important requisite of spray fluids is good adhesive power; the deposit left on drying should not easily be washed off by rain. Materials which enhance spreading powers also tend to increase adhesivity, but special "stickers," such as gums, molasses, fish oil, are sometimes added (see, *e.g.*, Hood, *U.S. Dept. Agric., Tech. Bull.* 111, 1929).*

Dry sprays or dusts must be extremely fine powders of suitable apparent density and must not tend to "ball"; they must also adhere well. The most important advantages possessed by dusts over liquid sprays are the elimination of the need for a water supply, a reduction

* The physics of spray fluids, including problems of emulsification and miscibility, and of spreading and wetting powers and adhesivity, has received much attention from research workers in recent years. The subject cannot adequately be dealt with here. A brief summary is given by Wardle, "Problems of Applied Entomology," Manchester, 1929, p. 147 *et seq.*; see also Woodman, *J. Pom. and Hort. Sci.*, iv., 38, 78, 95, 184, 1924-25; v., 43, 1925; vi., 313, 1928; *J. Agric. Sci.*, xvii., 44, 1927.

INSECTICIDES AND FUNGICIDES (*Continued*)—

in the time required for application and in the amount of labour necessary, and a simplification of the preparations, since dusts may be purchased ready for use. As a rule, however, a greater number of applications are necessary with dusts than with sprays to achieve the same results, the materials are more expensive, and dusting has not so far been successful in replacing winter and early spring spraying. It would appear that there is a place for both dry and wet sprays.

Fumigants must be easily generated and readily diffusible in air; their use is only suitable in enclosed spaces.

It is proposed to touch briefly on the main facts relative to each of the more important insecticides and fungicides in general use.

For the purpose of classification it is convenient to divide *insecticides* into two main groups, depending on their mode of action and the feeding habits of the insects against which they are employed. The mouth parts of many insects consist of strong biting jaws with certain accessory organs, by means of which the food is actually bitten off and chewed; these may be known as *biting* insects, and include beetles, grasshoppers, and the caterpillars of moths and sawflies. Others have the mouth parts arranged in the form of a proboscis or trunk which is adapted for piercing or boring and through which juices or liquefied tissues are sucked up; they may be distinguished as *sucking* insects, and include bugs, aphides, and scale insects. Pests belonging to the former group—those with biting jaws—may be killed by covering the foliage of the plants on which they feed with a suitable poison which will be consumed with the food. Sucking insects, however, cannot be dealt with in this way, since they feed only on the juices of internal tissues reached by means of the slender trunk-like mouth parts. The control by insecticides of pests of this group, therefore, involves the use of materials which will kill by actual contact, *i.e.*, which will, when in contact with the body of the insect, tend either to block up the minute breathing pores (spiracles) and so cause suffocation, or penetrate into the body either through the spiracles or by absorption through the body wall. We may therefore divide insecticides into:

(1) Contact poisons, used primarily against sucking insects (bugs, aphides, etc.) and hibernating forms.

(2) Internal or stomach poisons, used against biting insects (caterpillars of moths and sawflies, beetles, etc.) and acting through the alimentary canal. This is not, however, a rigid classification, since a contact poison may, for example, be used against both biting and sucking insects, and certain substances may act both as contact and internal poisons. In either case, the result is finally attained by the toxic action of the chemical on living cells.

Insecticides acting as Contact Poisons—The chief groups of substances which come under this heading are alkalies, coal-tar distillates, mineral oils, vegetable oils and soaps, some sulphur compounds, and products derived from certain plants. Included among them are a number of spray fluids, collectively known as winter washes, which are used

INSECTICIDES AND FUNGICIDES (*Continued*)—

for the destruction of eggs and other winter stages of insect pests of fruit trees and bushes, and for general cleansing purposes.

Alkali Washes—The older types of winter washes were made from lime or caustic soda. A hot lime wash (56 lbs. quicklime, 50 gallons water) is made by slaking the lime and then adding water, while still hot, until the mixture can be strained through a coarse sieve. Caustic soda is used at a strength of 2 or 2½ per cent. dissolved in water; sometimes 1 per cent. caustic soda with 1 per cent. potassium carbonate is recommended. "Woburn Wash," which has given useful results, consists of a paraffin-soft-soap emulsion with the addition of 2 per cent. caustic soda. Washes of this type, while efficient for generally cleansing fruit trees by removing moss, lichen, and rough bark, are not satisfactory for destroying insect eggs and have now to a large extent been superseded by tar distillates.

Tar-Distillate Washes—The preparation of insecticides from certain fractions of coal tar is a comparatively recent discovery, and it is only since about 1922 that these washes have been manufactured in Great Britain. They were in use for some years previously in Holland and Germany. They consist of tar distillates of the wood preservative type ("carbolineum") combined with emulsifying agents so that they mix perfectly with water to give a milky emulsion. A great many proprietary brands are now on the market.

These sprays are true egg-killing as well as general cleansing washes; a long series of field experiments has proved their value for the destruction of eggs of Aphides, Apple Sucker, Winter Moth, and other pests (Petherbridge and Weston, *J. Min. Agric.*, xxxiii., 332, 592, 1926; Jary, *J. Min. Agric.*, xxxiii., 753, 1926; xxxiv., 1107, 1928). They can be applied only during winter when the trees are dormant, since foliage and developing buds are liable to be injured. Strengths of 6-7½ per cent. are generally recommended against Aphid and Apple Sucker eggs, and 7½-10 per cent. against moth eggs. The precise mode of action of these fluids upon insect eggs is not known; it is probably mainly a mechanical smothering by a persistent film of oil. It is curious that tar distillates do not kill the eggs of the fruit-tree Red Spider (*Oligonychus ulmi*); there is, indeed, good evidence that, where these washes are in constant use, Red Spider is liable to increase unless other measures are taken, perhaps owing to the destruction of predaceous enemies which normally tend to keep it in check.

The ordinary type of tar-distillate spray also fails to kill any large pro-

with which the fruit grower has to contend, and it is satisfactory that recent experiments have shown that a wash prepared from a particular fraction of the tar distillate (a high boiling-point neutral fraction) will give commercial control of Capsid Bugs (Staniland and Walton, *J. Min. Agric.*, xxxvi., 517, 828, 1929).

An aromatic nitro compound, 3:5 dinitro-*o*-cresol, has also been found to possess very high toxicity to insect eggs. Field experiments with spray fluids containing this substance or its sodium salt, at

INSECTICIDES AND FUNGICIDES (*Continued*)—

concentrations between 0·25 and 0·5 per cent., have given results similar to those obtained with tar distillates. Dinitro-*o*-cresol is obtainable on a large scale at a comparatively low price, but owing to its yellow staining properties has only been employed experimentally (Gimingham, Massee, and Tattersfield, *Ann. App. Biol.*, xiii., 446, 1926; Gimingham and Tattersfield, *J. Agric. Sci.*, xvii., 162, 1927; *J. Pom. Hort. Sci.*, vii., 146, 1928).

Mineral Oils—For many years paraffin or burning oil (kerosene) was the only petroleum product utilized to any extent as an insecticide, but, more recently, much interest has also been taken in heavier oils of the lubricating oil type. Undiluted paraffin is used to kill mosquito larvæ in water by spreading it over the surface; it is also applied by hand to the trunks and branches of fruit trees for the control of scale insects and Woolly Aphis, but, owing to a severe scorching action, it cannot be sprayed on to foliage. In order to get over this difficulty, emulsions are employed. These should not contain more than 2½ per cent. of paraffin for summer use, though much stronger emulsions can be used as dormant winter washes. Suitable formulæ are:

	Winter Strength.	*Summer Strength.*
Paraffin oil	1 gallon	2 pints
Soft soap	1½ to 2 lbs.	1 lb.
Water	10 gallons	10 gallons

The soap is dissolved in about 1 gallon of boiling water, the solution moved from near any flame and the paraffin at once added. The mixture is then thoroughly churned by means of a syringe until completely emulsified, when the remaining 9 gallons of water may be added and the whole well mixed. The winter strength emulsion is suitable against scale insects and the overwintering stages of many pests, and the summer strength against sucking insects of all kinds.

The use of emulsions of heavier petroleum oils as "delayed dormant" sprays, *i.e.*, applied at the period when insect eggs are hatching, has been much studied in America in recent years, and these washes are now widely used in the fruit-growing districts (see A. F. Mason, "Spraying, Dusting and Fumigating of Plants," p. 56 *et seq.*, 1928). A heavy oil emulsion, with Bordeaux Mixture as emulsifier, is also successfully employed for the control of the Onion Fly (Glasgow and Cook, *J. Econ. Ent.*, xxii., 683, 1929). It has been found that the injurious action of the heavier (high boiling point) oils on foliage is due largely to the presence of impurities, and concentrated emulsions of highly refined heavy petroleum oils are now on the market which can be used with safety; they give good control of Red Spider and other pests, but are somewhat expensive.

"Miscible oil" preparations, which can be diluted direct with water, have found considerable favour in America (Melander, Spuler, and Green, *Wash. Agric. Exp. Sta., Bull.* 184, 1924; *Bull.* 186, 1926). They are prepared by the addition to a petroleum-soap emulsion of a third

INSECTICIDES AND FUNGICIDES (*Continued*)—

substance soluble in the petroleum; cresylic acid, vegetable oils, or sulphonated oils are commonly used. "Miscible oils" contain up to 90 per cent. of oil.

Oil emulsions appear to penetrate into the tracheæ (breathing tubes) of insects not only as such, but also as a film of oil after the emulsion has broken, thus probably bringing about death by suffocation or by interference with the action of the enzymes concerned with respiration (Shafer, *Mich. Agric. Exp. Sta., Tech. Bull.* 11, 1911; Moore and Graham, *J. Agric. Res.*, xiii., 523, 1918; DeOng, Knight, and Chamberlin, *Hilgardia*, ii., No. 9, 1927).

Vegetable Oils and Soaps—Certain vegetable oils are sometimes utilized as a constituent of the "miscible oils" referred to above, and they have been employed, in emulsion, directly as insecticides. Rape oil at 1 per cent. proved very efficient against Aphides and young larvæ of Moths and Sawflies (Staniland, *Rept. Long Ashton Res. Sta.*, p. 78, 1926).

The importance of soaps (the alkali salts of higher fatty acids) in spraying technique is mainly due to their effect on the physical properties of the spray, but, in addition, they have a quite definite insecticidal action. Many kinds of Aphides can be destroyed by nothing more complicated than a strong soap solution. Investigations on the toxicity of the fatty acids themselves have shown that some of them, notably capric and lauric acids, are very highly toxic to Aphides; and it has been proposed in America to use a commercial preparation containing these acids as a substitute for nicotine (Seigler and Popenoe, *J. Agric. Res.*, xxix., 259, 1924; Tattersfield and Gimingham, *Ann. App. Biol.*, xiv., 331, 1927).

Sulphur and Sulphur Compounds—Sulphur itself cannot strictly be called an insecticide, but it is a valuable acaricide; dusting with fine sulphur is an effective means of controlling various mites, particularly "Red Spider," on hops, strawberries, and greenhouse plants. Lime sulphur (solution of calcium polysulphides), in addition to its high value as a fungicide (see p. 606), is also an important insecticide and acaricide. At a strength of 1 part in 12 of water it is employed as a winter wash, and is specially effective against Scale Insects and Red Spider. The best means known for combating the Big-Bud Mite in black currants also involves spraying with lime sulphur at 1 in 12 (Hatton, Amos, and Tydeman, *J. Pom. and Hort. Sci.*, v., 124, 1926). Barium polysulphide has been proposed as a dry substitute for lime sulphur (Scott, *J. Econ. Ent.*, viii., 206, 1915), but does not appear to be as efficient. Liver of sulphur (sodium or potassium polysulphides) is also sometimes used against Scale Insects and Red Spider.

The mode of action of lime sulphur on Scale Insects has been investigated by Shafer (*Mich. Ag. Exp. Sta., Tech. Bull.* 11, 1911; *Tech. Bull.* 21, 1915). Calcium polysulphides have a high power of absorbing oxygen, and it appears that the waxy covering of the Scale Insect is rendered less permeable to oxygen and is also softened and caused to adhere to the plant, the insect thus being deprived of a sufficient supply of oxygen.

INSECTICIDES AND FUNGICIDES (*Continued*)—

Nicotine—The insecticidal properties of tobacco extract have been known for many years, and it is to the presence of the alkaloid nicotine in the tobacco plant that these properties are due. Pure nicotine is a colourless liquid, boiling at 247° C., which becomes dark in colour on keeping. It is definitely volatile at ordinary temperatures and readily soluble in water; it is a base, like all alkaloids, and forms salts with acids, occurring in tobacco combined with malic and citric acids. The production of nicotine from waste tobacco or direct from certain coarse-growing varieties of *Nicotiana* which contain a high percentage of the alkaloid is now carried out on a large scale. Nicotine most commonly comes on the market either as the free alkaloid (commercially pure nicotine is an almost black, somewhat viscous liquid containing 95 to 98 per cent.), or as a salt, nicotine sulphate, containing 40 per cent. of the alkaloid. Different grades of tobacco juice or extracts, containing 1 to 10 per cent. of nicotine, are also largely used, particularly in France. Nicotine and nicotine sulphate keep well, but the former is hygroscopic and absorbs water (McDonnell and Young, *U.S. Dept. Agr., Bull.* 1312, 1925). Certain commercial preparations containing nicotine and soap have, however, proved unsatisfactory owing to deterioration on storage, a change due to chemical action and not to actual loss of nicotine by volatilization (McDonnell and Nealon, *Ind. Eng. Chem.*, xvi., 819, 1924; xxi., 70, 1929). Combinations of nicotine with fatty acids, such as nicotine oleate, have also been placed on the market.

Nicotine is a highly effective contact insecticide at strengths between 0·05 and 0·1 per cent., and is generally used with soap to assist wetting, spreading and penetration. Thus, $\frac{3}{4}$ to 1 fluid oz. of nicotine, $\frac{1}{2}$ to 1 lb. of soft soap, per 10 gallons of water forms a spray fluid commonly recommended against aphides of all kinds, many scale insects, young caterpillars and other pests. Nicotine is also sometimes added to oil emulsions. With the saline waters in certain districts, soft soap cannot be used and some other "spreader" such as sodium caseinate must be substituted (see Petherbridge and Kent, *J. Min. Agric.*, xxxiii., 51, 1926).

Nicotine sulphate is practically non-volatile and is less toxic than the free base; its action depends indeed on the production of nicotine by means of an alkali. Soap solution is generally employed for this purpose, the alkali formed by hydrolysis of the soap liberating free nicotine from the sulphate. Lime-nicotine sulphate sprays and heavy oil emulsions containing nicotine sulphate are also used in America.

A detailed investigation by R. E. Smith in California (*Calif. Agric. Exp. Sta., Bull.* 336, 1921) first drew attention to the possibility of applying nicotine in *dust* form by impregnating a suitable fine powder with the liquid. Numerous other experiments followed, and nicotine or nicotine sulphate dusts are now in common use in the United States,* the carrier powder in the case of the sulphate being an alkali,

* For further information with reference to nicotine dusts and the relative merits of dusts and sprays see Thatcher and Streeter, *New York Agric. Exp. Sta., Bull.* 501, 1923; Headlee and Rudolfs, *New Jersey Agric. Exp. Sta., Bull.* 381, 1923.

INSECTICIDES AND FUNGICIDES (*Continued*)—

calcium carbonate or hydroxide. Quite recently, much practical interest has been taken in nicotine dusts in England, and it is claimed that good results against the notorious Apple Capsid Bug and other pests have been obtained (see "Dusting of Fruit Trees," by Turnbull, *The Fruitgrower*, April 25, May 2 and 9, 1929).

Nicotine is expensive, but, like other plant products, possesses the great practical advantage, whether in the form of spray fluid or dust, of causing no injury whatever to plants. It must not be forgotten, however, that it is excessively poisonous to human beings and all higher animals, and should be used with very great care.

The physiological action of nicotine upon insects is still by no means fully elucidated. It appears to cause paralysis of the nerve centres, gaining entrance through the spiracles and tracheæ, and, according to McIndoo, acts only in the vapour phase (*J. Agric. Res.*, vii., 89, 1916). Nicotine appears to be almost unique among the alkaloids in possessing high toxicity to insects. Two others, cytisine occurring in broom and other leguminous plants, and lobeline found in *Lobelia inflata*, are known to have physiological effects on the higher animals similar to those produced by nicotine. These two alkaloids tested on the Black Bean Aphis were found to have moderately high values as contact insecticides, but were not so toxic as nicotine; and, of a number of other alkaloids tested, only eserine approached nicotine in intensity of toxic action (Tattersfield, Gimingham and Morris, *Ann. App. Biol.*, xiii., 424, 1926).

Quassia—An extract prepared by maceration of quassia chips (obtained from the trees *Quassia amara* and *Picrasma excelsis*) in water or soap solution has long been used as a spray against aphides, especially by hop growers against the Hop-Damson Aphis. The extracts contain a bitter principle known as quassiin, which is non-poisonous to higher animals, but is not a powerful insecticide. McIndoo and Sievers have shown that most insects are but little affected by quassia extracts, a few species of Aphides only being sensitive to their action (*J. Agric. Res.*, x., 497, 1917).

Derris or Tuba-Root—Among a number of tropical leguminous plants which are used by the natives of their country of origin as fish poisons, there are some possessing powerful insecticidal properties. The most important of these are certain species of *Derris* (*Deguelia*), *D. elliptica* and *D. uliginosa*. The poisonous principles are contained in the roots and consist of a colourless crystalline compound, rotenone (more commonly known as tubatoxin), and a yellow resin named "derride." The chemical constitution of rotenone has not yet been worked out; it is excessively toxic to many insects.

Tuba root was used as an insecticide many years ago by the Chinese market gardeners in Singapore, and it is now imported into England and America chiefly from the Malay States where it is cultivated. The finely powdered root can be worked up with water and soap and used directly as a spray; or it can first be extracted with a suitable organic solvent and the extract used. In England it is utilized mainly by manufacturers for the preparation of proprietary insecticides, and

INSECTICIDES AND FUNGICIDES (*Continued*)—

is employed specially against caterpillars; it is also effective for the control of Warble Fly maggots in cattle (Gaut and Walton, *Rept. to Worcs. C.C.*, October, 1929). Derris is probably a nerve poison, and is said to act both as a contact insecticide and a stomach poison (McIndoo, Sievers, and Abbott, *J. Agric. Res.*, xvii., 177, 1919).*

Several species of *Tephrosia* and *Lonchocarpus*, also used as fish poisons, have more recently been found to be of interest as possible sources of insecticides (Tattersfield, Gimingham, and Morris, *Ann. Appl. Biol.*, xiii., 424, 1926). Extracts of the leaves and seeds of *Tephrosia vogelii* from Africa and the West Indies, of the roots of *T. toxicaria* from British Guiana, of the roots of *T. macropoda* from South Africa, and of the roots and stems of two species of *Lonchocarpus* from British Guiana, known as black and white haiari, were all found to be highly toxic to the black Bean Aphis and other insects. The haiaris contain considerable quantities of rotenone, the compound which occurs in *Derris*. "Cube," a Peruvian plant used as a fish poison, is also reported to contain rotenone and to be a strong insecticide (Clark, *Science*, lxx., 478, 1929). Attempts are being made to utilize some of these plants on a commercial scale.

Pyrethrum—The ground flower heads of certain species of *Chrysanthemum* (*Pyrethrum*) have long been known as "insect powder." *Chrysanthemum cinerariæfolium* Trev. provides Dalmatian insect powder, and *C. coccineum* Willd. and *C. marschallii* Ascher (*roseum* Bieb.) provide Persian or Caucasian insect powder. The first-named species is the most important: a native of Dalmatia and Albania, it is largely cultivated in the Mediterranean region and in Japan, whence considerable quantities are imported to England and America. Cultivation of this plant has also lately been encouraged in Switzerland and in France and Morocco (see, *e.g.*, Chevalier, *La Grande Revue Agricole*, p. 493, March, 1928; Perrot, *Compt. rend. Acad. Agr. France*, xv., 885, 1929), and within the last few years it has been grown experimentally in England (Fryer and Stenton, *J. Min. Agric.*, xxxiii., 916, 1927; Fryer, Tattersfield, and Gimingham, *Ann. Appl. Biol.*, xv., 423, 1928).

The insecticidal principles of pyrethrum (pyrethrin I. and II.) have been isolated and studied by Staudinger and Ruzicka (*Helv. Chim. Acta.*, vii., 177, 1924). A chemical method for the determination of the pyrethrins in pyrethrum, based on the researches of Staudinger and his co-workers, has been worked out by Tattersfield, Hobson, and Gimingham (*J. Agric. Sci.*, xix., 266, 1929).

Pyrethrum may be used as a dust, or in the form of an extract.

Extracts prepared with organic solvents are more active insecticides than those made by maceration in water. Soap preparations known as "savon-pyréthre" have been much used in France, but a slow reaction takes place between soap and the pyrethrins resulting in loss of insecticidal value, and it is better to add the soap to the spray only

* For further information on the chemistry and toxicity of *Derris* species see Fryer, Stenton, Tattersfield, and Roach, *Ann. Appl. Biol.*, x., 1, 18, 1923.

INSECTICIDES AND FUNGICIDES (*Continued*)—

shortly before it is to be used. Oil extracts of pyrethrum are now largely used as fly sprays (Twinn and Hermann, *Sci. Agric.*, viii., 441, 1928), and, if suitably emulsified, can also be utilized as horticultural sprays.

Different species of insects differ in their degree of resistance to the action of pyrethrum. It is, however, highly efficient against many species of Aphides, Leaf Hoppers, and other sucking insects, and also against the caterpillars of many moths, and Sawflies. Cockroaches and some beetles are also sensitive to its action, whereas the caterpillars of some Noctuid Moths are highly resistant. Pyrethrum is practically non-poisonous to man and other warm-blooded animals, and properly prepared sprays are harmless to plants.

Insecticides acting as Internal Poisons—The internal or stomach poisons used for the control of "biting" insect pests (of which many beetles and caterpillars are examples) are chiefly compounds of arsenic or fluorine; they are sprayed or dusted on to the food plants or mixed with some form of bait.

Arsenious Oxide (*White Arsenic*, As_2O_3) *and Sodium Arsenite* (Na_3AsO_3) *and Arsenate* (Na_3AsO_4)—These compounds are unsuitable for use as spray fluids since they are liable to cause severe foliage injury. They are, however, utilized in poison baits for locusts and other pests (see, *e.g.*, Granovsky, *J. Econ. Ent.*, xix., 211, 1926; Ryan, *J. Econ. Ent.*, xxi., 682, 1928).

Paris Green—This was the first of the arsenical compounds to be used as an insecticide. It is a complex copper aceto-arsenite, but is variable in composition. It gives a less satisfactory suspension in water and is more liable to cause foliage injury than lead arsenate (see below), which has now to a great extent taken its place as a spray, though improved types of Paris green are used in Germany. Paris green is, however, generally chosen where a poison bait is used for control of soil pests such as Cutworms or Surface Caterpillars (larvæ of certain noctuid moths), Leather Jackets (larvæ of crane flies) and Slugs. A mixture of 20 lbs. bran and 1 lb. Paris green moistened with about 1 gallon water has been found to give very successful results. This amount is about sufficient for 1 acre and should be thinly broadcast (*Min. Agric. Leaflets* Nos. 11, 33, and 132; Thompson, *Welsh J. Agric.*, ii., 228, 1926; iv., 342, 1928). A similar bait, sometimes with the addition of molasses and fruit juice, is employed against Locusts and Grasshoppers.

London Purple—This material is a mixture of calcium arsenite and arsenate, and was employed for the same purposes as Paris green. It is, however, of very variable composition, and is now little used as an insecticide.

Lead Arsenate—Since about 1895 lead arsenate has become the standard arsenical insecticide. It is almost insoluble in water and is very toxic to insects; it can be prepared as a very finely divided precipitate which remains suspended in water for long periods, and it has good adhesive and covering powers. The chief drawback to its

INSECTICIDES AND FUNGICIDES (*Continued*)—

employment—and this applies to all arsenical compounds—is the fact that it is highly poisonous to man and the higher animals.

Commercial lead arsenate commonly consists of the diplumbic hydrogen arsenate ($PbHAsO_4$) always referred to in America as acid lead arsenate, but there are also preparations containing basic lead arsenates or mixtures of the two. Lead arsenates are sold either as dry powders or as pastes, the former containing the equivalent of 30 to 33 per cent. arsenic pentoxide and the latter 15 to 20 per cent. The pastes have the advantage of giving a spray fluid of somewhat better physical properties than the powders, and are commonly used at the rate of 4 to 5 lbs. per 100 gallons of water.* They are generally used without the addition of any "spreader," though lime casein or a saponin product is sometimes incorporated; soap is unsuitable.

The injurious action of certain arsenical sprays on foliage is due to the presence of soluble arsenic compounds liable to be formed by hydrolysis; the addition of slaked lime to the wash in order to reduce this risk is often recommended (Van der Meulen and Van Leeuwen, *J. Agric. Res.*, xxxv., 313, 1927; Swingle, *J. Agric. Res.*, xxxix., 393, 1929). On the other hand, the more stable the arsenical, the less poisonous is it to insects; Paris green is more active than lead arsenate because it is more easily hydrolyzed and more readily gives soluble arsenic when ingested by an insect. The ideal compound would therefore appear to be one which strikes a mean as regards stability and insolubility, yielding sufficient soluble arsenic to cause rapid poisoning when consumed by an insect, but not sufficient on the surface of the leaves to produce serious foliage injury.

Calcium Arsenate—In recent years calcium arsenate has come into use, particularly in the United States. Commercial preparations usually contain an excess of lime, and are mixtures of rather indefinite basic arsenates (Goodwin and Martin, *J. Agric. Sci.*, xvi., 596, 1926). They are specially suitable for use in powder form, and calcium arsenate dust is now the standard chemical means adopted in attempting to control the Cotton Boll Weevil.

Sodium Fluoride (NaF)—Many attempts have been made to find satisfactory substitutes for lead and calcium arsenates which shall be non-poisonous or less poisonous to human beings, and special attention has been directed to compounds of fluorine. Sodium fluoride acts as an internal poison to insects, and is frequently used in poison baits for Cockroaches, Earwigs, and other pests (Ripley, *Bull. Ent. Res.*, xv., 29, 1924; Gibson and Glendenning, *Canad. Ent. Dept., Circ.* 24, 1925). It is moderately soluble in water and the solution causes severe foliage injury, so that it cannot be employed as a spray fluid.

Sodium and Calcium Silicofluorides (Na_2SiF_6,$CaSiF_6$)—These compounds, also known as fluosilicates, are readily obtainable in large quantities, are much less poisonous to man than lead arsenate or sodium fluoride, and, used as dusts, have given successful results

* Where frequent spraying with lead arsenate is necessary, as in America against Codling Moth, the problem of the amount of arsenical residue left on the fruit becomes a serious one.

INSECTICIDES AND FUNGICIDES (*Continued*)—

against a variety of insects (Marcovitch, *Tennessee Agric. Expt. Sta., Bull.* 134, 1926; *Bull.* 139, 1928; Walker and Mills, *Ind. Eng. Chem.*, xix., 703, 1927). Sodium silicofluoride is much less soluble in water than sodium fluoride, but is liable to cause foliage injury under certain conditions; the risk of such injury is much reduced by the addition of slaked lime.

Mercuric Chloride (*Corrosive Sublimate*, $HgCl_2$)—This substance finds use as an insecticide for special purposes, as, for example, for the control of the maggots of certain vegetable root flies (Brittain, *Dept. Nat. Resources Nov. Scot., Bull.* 11, 1927; Jary, *Gard. Chron.*, p. 250, March 30, 1929). Quite recently, mercurous chloride (calomel, HgCl) has also been found effective (Glasgow, *J. Econ. Ent.*, xxii., 335, 1929).

Hellebore—The underground parts of white hellebore (*Veratrum album*) contain an insecticidal principle, and when finely ground are sometimes utilized as a stomach poison. The powder may be used as a dust or with soap solution (2 lbs. per 10 gallons), and can safely be applied to delicate flowers and fruits.

Fumigants and Soil Insecticides—The employment of chemicals in the vapour form for the control of pests is known as fumigation, and is a valuable method under certain conditions, as, for example, in greenhouses.

Hydrocyanic Acid (HCN)—Hydrocyanic acid is a colourless liquid boiling at 26° C. The gas can be easily produced, diffuses readily in air, is very poisonous to insects and other animals and less harmful to plants. Its action upon insects is apparently an interference with the respiratory enzymes. The high toxicity of hydrocyanic acid gas for man necessitates rigid precautions when it is used as a fumigant; none the less, it is employed to a large extent for the control of scale insects and other pests on citrus fruits, for the destruction of grain and stored product insects, and for glasshouse fumigation against White Fly. (See Glasshouse Crops.) The introduction in recent years of calcium cyanide, a powder which reacts with the moisture of the air and gives off hydrocyanic acid gas, has simplified the use of this compound for many purposes. Calcium cyanide may be used under certain conditions as a soil insecticide (Miles and Petherbridge, *Ann. Appl. Biol.*, xiv., 359, 1927; *J. Min. Agric.*, xxxiii., 931, 1927).

Naphthalene ($C_{10}H_8$)—Under carefully controlled conditions, naphthalene vapour is recommended against the greenhouse Red Spider (see Glasshouse Crops). Naphthalene is also commonly used as a soil insecticide, with rather variable results, for the control of Wireworms, Leather Jackets, Cockchafer grubs, and other soil pests. Recent experiments indicate that powdered naphthalene at the rate of about 2 ozs. per square yard acts as a powerful repellent to the Cabbage, Carrot, and Onion Root flies, to a great extent preventing egg-laying and saving the crop from the depredations of the maggots.

Paradichlorobenzene ($C_6H_4Cl_2$)—The use of this chemical has largely solved the problem of the control of the Peach-Tree Borer, a serious pest in America. It can be used as a soil dressing, and is recom-

INSECTICIDES AND FUNGICIDES (*Continued*)—

mended for the fumigation of bulbs to destroy Aphides (Essig, *Calif. Agric. Expt. Sta., Bull.* 411, 1926; Stenton, *J. Min. Agric.*, xxxii., 1037, 1926).

Carbon Disulphide (CS_2)—This is perhaps the best known soil fumigant. It is a volatile liquid, easily inflammable, and the vapour is heavy, diffusing fairly readily in the soil. It is very toxic to insects. Injected into holes round the base of the plants, it has been successful against the Phylloxera of the vine in France, and where the expense is justified can be used to destroy many soil pests. Emulsions of carbon disulphide have been employed for soil fumigation in America (Leach and Johnson, *U.S. Dept. Agric., Bull.* 1332, 1925; Cory and Sanders, *J. Econ. Ent.*, xxii., 556, 1929). Carbon disulphide is also used for the fumigation of stored products. (See Grain Insects.)

Potassium Sulphocarbonate (K_2CS_3)—This substance is soluble in water and slowly gives off carbon disulphide on contact with carbon dioxide. It is a powerful soil insecticide, but too expensive for general use (Molinas, *Prog. Agric. et Vitic.*, xxxi., 374, 1914). *Potassium Xanthate* (potassium ethyldithiocarbonate, $KS_2COC_2H_5$), which also slowly yields carbon disulphide, has been proposed for use in a similar manner (DeOng, *Ind. Eng. Chem.*, xviii., 52, 1926; xx., 912, 1928).

Nicotine—Many proprietary fumigants consist of tobacco shreds or some mixture containing nicotine which, when ignited, slowly smoulders, giving off nicotine vapour. Aphides and other pests in greenhouses can thus be killed.

Sulphur is also used as a greenhouse fumigant, and special forms of heating apparatus for volatilizing the sulphur are on the market. Great care is necessary to see that the sulphur does not ignite, since the sulphur dioxide then produced is most toxic to plants. *Sulphur dioxide* is itself used for fumigation of dwelling houses and ships.

Tetrachloroethane ($C_2H_2Cl_4$)—This liquid is often used under glass for the control of White Fly. (See Glasshouse Crops.)

Carbon Tetrachloride (CCl_4), *Chloropicrin* (CCl_3NO_2), and other organic compounds are employed for the fumigation of stored products.

Fungicides—The materials in general use as fungicides are few in number, being almost limited to sulphur and certain sulphur compounds and mixtures containing copper compounds. In addition, formaldehyde and some mercury and arsenic compounds find use as seed disinfectants. (See Seeds, Transmission of Diseases by.)

Bordeaux Mixture—By far the most important of the copper fungicides is made by the interaction of copper sulphate (blue vitriol) and lime, and is known as Bordeaux Mixture; it was first used as a fungicide on vines in the Bordeaux district in 1885 (Millardet, *J. d'Agri. prat.*, xlix., 1885).

The blue precipitate formed when milk of lime is mixed with copper sulphate solution consists of basic sulphates of copper which differ in composition according to the relative proportions of lime and copper sulphate. The precise nature of these compounds has been subject to much investigation (see Martin, "Scientific Principles of

INSECTICIDES AND FUNGICIDES (*Continued*)—

Plant Protection," London, p. 73 *et seq.*, 1928), but it cannot be said that the chemistry of Bordeaux Mixture is yet fully elucidated.

In practice, Bordeaux Mixture is commonly made with equal weights of quicklime and copper sulphate at the rate of 4 lbs. of each per 50 gallons of water, though for potato spraying the amount of quicklime may be reduced to 2½ lbs. per 50 gallons. No copper should remain in solution, since dissolved copper is seriously injurious to foliage. The quicklime is slaked and diluted with most of the water, the copper sulphate is added in the form of concentrated solution, and the mixture thoroughly stirred. Both constituents should be of high quality. Good quality hydrated lime (calcium hydroxide) may be used in place of quicklime* and is now on the market (Goodwin and Salmon, *J. Min. Agric.*, xxxiv., 517, 1927). When first formed, the precipitate is flocculent and easily remains suspended in the liquid, but on keeping, physical changes take place and it becomes much less suitable for spraying. Bordeaux Mixture should therefore be used as soon as possible after it is prepared.

Bordeaux Mixture, if well prepared, adheres to foliage in a remarkable manner, and the addition of "spreaders" or "stickers" is not usually necessary.

Various proprietary Bordeaux pastes and powders are obtainable, requiring only mixing with water, and thus saving trouble in preparation. They are largely used, but do not appear generally to give results as satisfactory as those obtainable with "home-made" Bordeaux Mixture. Dry Bordeaux powders for use as dusts are also widely employed, especially for potato spraying. They are applied when the leaves are wet with dew or rain, but are not generally so effective as the wet sprays. The subject of copper-lime dusts has been studied by Holland and his co-workers (*J. Agric Res.*, xxxiii., 741, 1926).

The two most important diseases against which Bordeaux Mixture is used in England are Potato Blight and Apple Scab, and the coating of the foliage with a film of an insoluble copper compound forms a protective device designed to poison the spores of the fungi and so prevent them from gaining entrance to the plant tissues. It is generally agreed that the copper must be rendered soluble before such poisoning action can take place, but it is still not quite certain exactly how this occurs. The view that the germinating fungus spore itself exerts a solvent action is supported by the work of Clark, of Schander, and of Barker and Gimingham (*Bot. Gaz.*, xxxiii., 26, 1902; *Landw. Jahrb.*, xxxiii., 517, 1904; *J. Agric. Sci.*, iv., 69, 76, 1911; vi., 220, 1914). Pickering and other workers ascribed the production of soluble copper to the action of atmospheric carbon dioxide (Pickering, 11th *Rept. Woburn Expt. Fruit Farm*, p. 22, 1910; Schmidt, *Centralbl. Bakt.*, II., lxi., 356, 1924), while it has also been put down to secretions from the surface of the leaves.

* In making Bordeaux Mixture, 6 lbs. of hydrated lime may be taken as equivalent to 4 lbs. of quicklime.

INSECTICIDES AND FUNGICIDES (*Continued*)—

A more or less severe "scorching" of the foliage and "russeting" of the fruit sometimes follows spraying with Bordeaux Mixture, and on certain varieties of apple this may at times cause serious losses. On the other hand, a marked general stimulation of the growth of sprayed plants is often observed.

Burgundy Mixture, a fungicide with properties similar to those of Bordeaux Mixture, is prepared by mixing solutions of copper sulphate and washing soda (sodium carbonate). This is known as Burgundy Mixture or Soda Bordeaux; it is widely used in Ireland and elsewhere for potato spraying, and is equal to Bordeaux Mixture in efficiency. The copper is precipitated in the form of a basic carbonate, but the chemistry of the reaction is rather obscure (Pickering, *J.C.S.*, xcv., 1409, 1909; Mond and Heberlein, *ibid.*, cxv., 908, 1919). The precise proportions of the constituents used in practice vary somewhat; 5 lbs. of washing soda dissolved in 5 gallons of water, and poured into 4 lbs. of copper sulphate dissolved in 35 gallons of water, gives a satisfactory mixture. It is generally considered that there is rather greater risk of spray injury from Burgundy than from Bordeaux Mixture.

Basic Copper Acetate—Some forms of verdigris ("verdet"), a mixture of basic copper acetates, are employed in France to a considerable extent for the same purposes as Bordeaux Mixture.

Ammoniacal Copper Compounds—Solutions of copper carbonate in ammonia or ammonium carbonate solution are effective fungicides, and they have the advantage of leaving but little visible deposit on the foliage or fruit. "Modified Eau Céleste" and "Cheshunt Compound" are examples of these preparations. The former is prepared by adding sufficient ammonia to Burgundy Mixture to dissolve the precipitate, giving a clear blue solution, while the latter consists of a mixture of copper sulphate and ammonium carbonate. (See Glasshouse Crops.)

Sulphur—Sulphur is perhaps the oldest known fungicide, and is widely used to control mildews (Hop Mildew, Vine Mildew, etc.) and other fungi which grow on the external parts of plants. Dusting sulphur in a very fine state of division is now available, prepared either by very thorough grinding or by sublimation (flowers of sulphur). There seems little to choose between the two forms (Goodwin and Salmon, *J. Min. Agric.*, xxxiv., 517, 1927). "Green sulphur," which is usually less fine, is an impure product containing about 50 per cent. of sulphur. So-called "colloidal" and "wetable" sulphur make possible its use as a spray; they are generally fine suspensions of sulphur in solutions containing a spreading agent (see, *e.g.*, Goodwin, Martin, and Salmon, *J. Agric. Sci.*, xx., 18, 1930). Sulphur is also utilized for fumigation.

Sulphur rarely causes any foliage injury, though cases of burning and defoliation have been reported in hot climates. The precise manner in which the fungus is killed is still under investigation; a discussion of the various views put forward is given by Martin, "Scientific Principles of Plant Protection," London, p. 60, 1928 (see also Martin, *J. Agric. Sci.*, xx., 32, 1930).

INSECTICIDES AND FUNGICIDES (*Continued*)—

Lime Sulphur—Lime sulphur competes with Bordeaux Mixture for the premier place as a wet spray fungicide. It is used for the control of Apple Scab, American Gooseberry Mildew, Apple Mildew, and other fungi. It is prepared by boiling together a suspension of slaked lime and sulphur, and should contain no other ingredients. Lime sulphur is best purchased in concentrated form, and most of the commercial products on the market, which need only dilution with water before use, are quite satisfactory. The important constituents of properly prepared lime sulphur are calcium polysulphides, and it is to the sulphur present in the form of polysulphides that the direct fungicidal action of these solutions is due (Goodwin and Martin, *J. Agric. Sci.*, xv., 96, 307, 1925; *Ann. Appl. Biol.*, xvii., 127, 1930). On exposure to air, dilute solutions of lime sulphur rapidly decompose with deposition of elementary sulphur.

Lime sulphur is employed both as a winter and a summer spray fluid. The winter strength commonly recommended for dormant trees is 1 part of concentrated stock solution (specific gravity 1·3) to 12 parts of water; in summer, the strengths used vary from 1 in 29 to 1 in 99 of water. The effect of the addition of spreaders to lime sulphur solutions has been studied by Goodwin and Martin (*J. Agric. Sci.*, xv., 476, 1925); soap cannot be used.

Certain varieties of apples and gooseberries are very sensitive to the action of lime sulphur, and unless the solutions used are weak, some defoliation and dropping off of young fruit may occur.

Liver of Sulphur—This name is applied to both sodium and potassium sulphides. They are readily soluble in water, the solution containing polysulphides of the alkalis which possess fungicidal properties similar to those of the calcium polysulphides in lime sulphur. Solutions of liver of sulphur are used at strengths varying from 1 oz. per 3 gallons to 1 oz. per 10 gallons of water. It is a valuable garden and greenhouse fungicide, but is more easily washed off by rain than lime sulphur. Soap can be added to assist wetting and spreading. Weak solutions are harmless to plant foliage, but stronger solutions may cause damage.

Ammonium Polysulphide—This solution, introduced by Eyre and Salmon (*J. Bd. Agric.*, xxii., 1118, 1916; xxv., 1494, 1919; xxvi., 821, 1919), acts much like liver of sulphur, but leaves little or no visible deposit on foliage and fruit. Concentrated solutions, requiring only dilution with water or soap solution before use, are obtainable on the market. Ammonium polysulphide causes no injury to foliage. It has been specially recommended against American gooseberry mildew (Nattrass, *J. Min. Agric.*, xxxiii., 265, 1926; xxxiii., 1017, 1927; xxxv., 161, 1928).

Combined Insecticides and Fungicides—The advantage of applying a spray fluid which shall act as fungicide and insecticide at the same time is obvious, and certain combinations are widely used, *e.g.*, nicotine and lime sulphur, lead arsenate and lime sulphur, lead arsenate and Bordeaux Mixture. There are, however, a great many factors to be taken into account in considering such combinations. The

INSECTICIDES AND FUNGICIDES (*Continued*)—
insecticidal or fungicidal efficiency, or both, may be destroyed or reduced by chemical reaction between the components; and the right time and method of application may not be the same for both. In England the lime sulphur-lead arsenate spray is the most important of such combinations, and has been fully investigated by Goodwin and Martin (*J. Agric. Sci.*, xv., 307, 476, 1925). The combination of Bordeaux Mixture with arsenical sprays has also been studied by Goodwin and Martin (*J. Agric. Sci.*, xviii., 460, 1928). C. T. G.

INSECT PESTS and Measures of Control—Of Fruit, see article at conclusion of Fruit; of Glasshouse Plants, see Glasshouse Crops; of Hops, see article at conclusion of Hops; of Pulse Crops, see article at conclusion of Beans; of Root and Forage Crops, see article at conclusion of Swedes and Turnips; of Sugar-Beet, see article at conclusion of Sugar-Beet. See also Insects, Beneficial; Insects, Measures of Controlling; and Plant Diseases and Pests, Legislation with Reference to.

INSECTS, BENEFICIAL—By no means all insects are destructive enemies of agriculture. Many are beneficial and some are of very great economic value. Most species of insects, for example, are preyed upon to a greater or lesser degree by other members of their class. The kinds exercising this control are parasites and predators whose activities result in the destruction of vast numbers of insects injurious to the farmer and fruit grower. Although it is not possible to evaluate directly the beneficial effects of these parasites and predators, there is good reason to believe that pest outbreaks are often correlated with fluctuations in their relative abundance.

Parasites include an immense number of different species which lay their eggs on, or within, the bodies of other insects. The larvae which emerge from these eggs devour the tissues of their hosts, which they eventually destroy. Some of the very minute parasites destroy insect eggs, but the majority of parasites attack larvæ or pupæ, while a smaller number confine themselves to adult insects. The most important parasites are the Ichneumon flies and their allies the Chalcids, together with the great group of true flies known as the Tachinids. It is noteworthy that a parasitic insect may, in its turn, be parasitized by smaller species of similar behaviour which are termed secondary parasites or hyperparasites: tertiary or even quarternary parasites are also known which afford the most complex examples of parasitism. Predaceous insects seek out and devour other insects which serve as their prey. Among the best known predators are Ladybirds and their larvæ, which are voracious devourers of Aphides, Mealy Bugs, etc. A single Ladybird larva may destroy twenty Aphides per day and nearly 500 in its lifetime. The larvae of Hover Flies and of Lacewing Flies, Ground Beetles and their larvæ, Dragonflies and

has led during the last forty years to their practical utilization in certain cases as natural controlling agents. Natural control, or

INSECTS, BENEFICIAL (*Continued*)—
biological control as it is termed, has consequently come to be recognized by the economic entomologist. It has been notably successful in certain cases where injurious insects have secured a footing in countries they did not previously inhabit, and have rapidly developed into dangerous pests. In such instances the noxious species have invariably been free from the attacks of parasites and predators which restrain them in the lands from whence the pests were derived. Biological control aims, therefore, at the restoration of a condition of natural equilibrium by the introduction of effective parasites or predators, as the case may be. An important factor in its success is the exclusion of all hyperparasites, the presence of which would be deleterious to the activities of the parasites it is desired to establish. The first successful example was achieved when the Australian Ladybird *Vedalia cardinalis* was introduced into California in 1888 to destroy the Cushion Scale (*Icerya purchasi*) of citrus fruits. The measure was so advantageous that it has been repeated in almost all citrus-growing countries where the pest has become introduced, with equally satisfactory results. In the Hawaiian Islands the Sugar-Cane Leaf-Hopper has been controlled by Chalcid parasites and a predaceous Capsid bug (*Cyrtorhinus mundulus*) introduced from Queensland and Fiji. The Cane-Borer beetle of those islands has also been largely kept in check by a Tachinid fly obtained from New Guinea, and the *Anomala* beetle has been very appreciably reduced by a Scoliid wasp from the Philippines. More recently great benefit has been derived from the introduction of a minute Chalcid *Aphelinus mali* from North America into New Zealand, where it is effectually destroying the Woolly Aphis of apple. The same species of Chalcid has also been introduced into England for the same purpose, but it does not promise to withstand the climatic conditions. Mention must also be made of the Coconut Moth in Fiji, which gives every promise of being controlled by a Tachinid fly brought in from Malaya. In England the recent extensive breeding and liberation of the Chalcid *Encarsia* in glass-houses for the purpose of controlling White Fly has given encouraging results, and its adoption as a practical measure seems to be ensured. The outlook for the biological control of insect pests is becoming more promising as our knowledge of the complex factors that are involved increases. In some parts of the world prolonged research has been going on for a number of years without the desired success being fully achieved. In other cases success has been realized with remarkable rapidity, but each has to be studied on its merits, and it is not possible to forecast the results. The growing practical importance of biological control is exemplified by the fact that the United States maintains a parasite laboratory at Hyères (France) for the study and importation of beneficial insects from Europe. Also, the Imperial Bureau of Entomology has recently established a similar laboratory at Farnham Royal (Bucks) for dealing with problems of biological control in various parts of the Empire.

Reference has only been made to biological control in so far as it concerns injurious insects introduced into a country from abroad.

INSECTS, BENEFICIAL (*Continued*)—

The utilization of indigenous parasites and predators in the control of a native pest has not so far proved a practical proposition. The avoidance of measures which are more destructive to beneficial insects than to noxious kinds is about all that can be advocated at the present time. The breeding and liberation of certain parasites and predators, in numbers presumably large enough materially to increase their population in a given locality, has been attempted, but no undoubted practical successes have so far been achieved.

Another type of biological control of much more recent birth is concerned with the utilization of plant-feeding insects as a possible means of controlling noxious weeds. In parts of the world certain introduced weeds have either resisted all attempts at cultural or chemical means of control, or such methods have proved economically impracticable. The first attempt to cope with such a situation by biological means was made in the Hawaiian Islands, where the plant *Lantana* had developed into a serious menace. The introduction and colonization in 1902-03 of a number of species of insect enemies of *Lantana* from Mexico led to beneficial results. Their effects are specially evident in prevention of seeding and thereby checking the plant re-infesting areas previously cleared. At the present time very encouraging results are being obtained in the biological control of prickly pear in Australia by the introduction of insects which feed on that plant in North America. Efforts are also being made to control blackberry, furze, and ragwort in New Zealand by entomological methods. Work of this character, however, needs exceptional precaution in the selection of species of insects not likely to attack cultivated plants or crops.

Insects are also beneficial in that many kinds are concerned in the pollination of flowers. Bees of diverse species are collectively the most important agents in this process. The hive bee, as is well known, visits a wide range of flowers; humble-bees are also important agents, particularly in the pollination of red clover; while many of the solitary wild bees perform an important function in spring in the pollination of orchard trees. There are, again, other insects which are solely concerned in the pollination of single kinds of flowers. Thus, in the case of the cultivated fig its flowers require to be pollinated from the wild or caprifig. The structure of the fig flower is such that its pollination requires the intervention of a small wasp, *Blastophaga psenes*. In California and elsewhere profitable fig growing did not become possible until this insect was introduced and could carry out its useful work.

Mention may also be made of the benefit man has derived from the use of honey, beeswax, silk, lac, cochineal, and cantharidin, all of which are insect products.

A. D. I.

INSECTS, MEASURES OF CONTROLLING—Readers will be aware that there is probably no crop grown which is not more or less subject to the attacks of insects and other animal pests; suggestions as to how to combat these pests will be found in the articles dealing with the more important crops, and it is not proposed to repeat this information

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

here, but rather to discuss in more general terms the principles underlying the control measures advised elsewhere. By way of introduction, however, it may be worth devoting a few paragraphs to the chief factors which bring about the control of insects in nature, since in practice our object must be to supplement these factors by artificial measures of control rather than to supplant them.

THE FACTORS REGULATING INSECT NUMBERS IN NATURE—The population of any species of insect varies in accordance with the food supply, the climate, and the destruction wrought by various natural enemies. A large population can exist only where food supplies are ample, the climate is favourable, and the losses due to the attacks of natural enemies are not too serious, whereas a reduction in numbers will at once result in the absence of any one of these favouring conditions.

Food Supplies—In wild and uncultivated country the question of food supplies is often of considerable importance: insects can only feed on a certain plant or range of plants, and where these plants are growing in a wood or jungle mixed with many other kinds, the difficulties of finding food may often prevent a species of insect from becoming numerous. When plants are cultivated as crops, however, exactly the converse is the case; the pests of any particular crop are provided with plots, fields, or even whole territories largely devoted to the very plant on which they feed, with the result that certain insects have every opportunity for increasing until they become pests. Thus, one of the factors which under natural conditions would tend to keep the numbers of certain species within bounds has been entirely eliminated by the methods of civilized agriculture.

Climatic Factors—The second important factor which influences insect numbers is the climate or weather. In the first place the climate of any country decides which species of insects are capable of living there, assuming a suitable food supply to be present. Thus, insects like the Army Worm (*Cyrphis unipuncta*) reach England not infrequently, but on account of the climate they appear to effect no permanent settlement and do no harm, although ample food is available. Unfortunately, it is not yet possible to forecast with any precision the potential geographical range of any pest, although entomological research is already giving useful information in this direction. The subject is of great importance, as most countries of the world now legislate against produce likely to bring in new pests, and it is very necessary to know which of these pests would be likely to settle if introduced. The view usually taken is that where a crop can be grown, there most of the pests known to attack that crop will persist, but this is, in fact, a very loose generalization, and frequently a crop which is carefully tended by man can survive in areas not suitable to the insect pest, while the converse may also be true, and a pest of one crop may thrive in another part of the world where that crop will not grow, the pest having found some alternative food plant.

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

The climate of any country is, however, more or less stationary, and as regards variations in insect numbers, weather—that is to say, the irregularities in the climate—is of far greater importance. In such a country as England, in which the weather is very unstable, with summers sometimes wet and sometimes dry, and winters occasionally cold but often mild, the weather is the great controlling factor, because no one group of insects ever gets the weather most favourable to it for many years in succession. We thus find certain kinds of pests increasing in a dry warm summer, only to be checked again the following year by cool moist conditions, when another group of insects favoured by such conditions becomes numerous, and so on. In countries where the weather of each season is always much the same in every year, weather factors are of less importance, but even then they are not negligible, because there are few countries not subject to occasional rain storms or hurricanes, or to an increase in the dominant characteristics of any season, such as a few additional degrees of frost or heat, which may make all the difference to the survival of some pest.

Natural Enemies—Finally, the last great form of natural control is that due to natural enemies—birds, insectivorous animals, predatory and parasitic insects, and disease-causing organisms. These natural enemies are of great importance everywhere, but are perhaps of greater importance in those countries with a stable type of weather—that is to say, where the influence of weather factors is reduced. So far as the relative importance of the different enemies is concerned, little is yet known as to insect diseases, except that they may cause a very heavy mortality. Death from disease often results where weather conditions are unfavourable, and it may then be regarded as a form of climatic control rather than as a separate agency.

Apart from disease, the place of which can hardly yet be estimated, insect predators and parasites are by far the most important. Under special circumstances they can unaided reduce a species of insect from the status of a serious pest to one of no practical importance. The fact, however, that, in spite of parasites and predators, insects nevertheless multiply to such an extent as to become pests, proves that the struggle between the two is by no means one-sided. For this there are many reasons; in the most simple case the rate of reproduction of the insect pest is much greater than that of the parasite, so that in spite of the efforts of the latter the pest can still increase in numbers; then, again, the parasites and predators are themselves subject to the attacks of other parasites and predators, which may kill off so many of the former as to prevent them from doing any good.

These and other complications arise in most instances, and it is quite exceptional for a parasite to wipe out a pest; generally a kind of balance is established, an abundance of a pest being followed by an increase in the numbers of the parasite and correspondingly a decrease in the numbers of the pest, and so on, neither side being finally victorious.

Finally, in point of importance come insectivorous birds and other animals, such as bats, toads, and lizards. In some quarters there is

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

a disposition to treat these enemies, and notably birds, as of almost paramount importance, but the evidence would not suggest that they approach in value the insect parasites and predators. That birds are most useful allies is undoubted, and that they should be encouraged by any means possible is also beyond question, but too much should not be expected of them.

Brief reference has now been made to the three great types of control to which insect pests are subject in nature, and the sort of picture which it is hoped the reader has obtained is as follows: On the one side is an enormous population of insect pests, encouraged to multiply by an almost unlimited food supply, while on the other is an army of natural enemies feeding upon these insect pests and increasing as they increase. Between these two is the crop, growing and attempting to make good the damage done by pests; while over all are the weather factors, encouraging first one pest, then another, sometimes favouring crops and sometimes pest, and sometimes the parasite.

ARTIFICIAL MEASURES OF CONTROL—It will be clear from what has already been said that where the farmer or planter deliberately attempts to control an insect pest he is interfering in a battle which is already going on and is not starting a separate war of his own; the crop may be regarded as struggling against the pest, which is also being attacked by numerous natural enemies. There are thus three possible methods of working. In the first place, assistance may be given to the crop to struggle more successfully against the pest; secondly, the pest itself may be attacked; and lastly, assistance may be rendered to the natural enemies of the pest, or they may be reinforced either in numbers or by the introduction of further species. In practice there is often some overlapping between the two first methods of working, because a measure which encourages the development of the crop may also directly affect the pest itself, and *vice versa*, but with such exceptions the three lines of work are distinct and convenient for discussion.

Measures affecting the Growing Crop—*The Use of Resistant Varieties*—If a number of distinct varieties of any agricultural or horticultural plant be grown side by side, it will usually be noted that the varieties do not all suffer equally from the attacks of different pests; for instance, if different kinds of potato are planted in soil containing Wireworms, the tubers of some varieties, such as Golden Wonder, will attract far more Wireworms and suffer far more injury than the others. It is thus clear that plants may themselves have inherent and hereditary qualities which render them susceptible or resistant to the attacks of certain pests; in principle, then, the most simple and least troublesome method of preventing loss by any pest is to grow only varieties of crops which are sufficiently resistant to attack. Unfortunately in practice this method is one of the most difficult to employ, because there is no known method of creating any pre-arranged and inheritable quality in a plant (or animal for that matter). We cannot, for instance, as yet take a susceptible variety of a plant, and

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

so treat it that its descendants acquire an inherited resistance to any pest. What is possible, however, is to search out some plant or some variety which itself has developed this characteristic, and then by methods of plant breeding to attempt to combine the characteristic of resistance to some pest with such other essentials as high yielding capacity or high quality. We are thus dependent on the problem having been partially solved for us by the plant itself, but even then we may have years of work ahead before a commercially useful resistant variety is available. When it is further remembered that most important crops are attacked by a whole range of pests, it is clear that the chance of combining in one variety resistance to a number of different pests is rather small, and that for many years to come the method can only have a limited application. This statement must not be taken as discouraging further work on the production of pest-resistant varieties, but rather to indicate that rapid success is unlikely.

In regard to the achievements already attained, the classic instances are those of varieties of vine resistant to *Phylloxera* and of apple stocks resistant to Woolly Aphis. In these cases it was observed that certain vines of the American sub-genus *Euvitis* were resistant to the root form of the *Phylloxera*, and that certain apple varieties, notably Northern Spy, were resistant to Woolly Aphis, and the combination of quality, yield, etc., with that of resistance was obtained by grafting the valuable European vines (*Vitis vinifera* and *V. silvestris*) on *Euvitis* stock (*E. rupestris* and others), and different varieties of apple on Northern Spy stock. The work is still proceeding, notably in regard to apples, and certain Research Stations in England are attempting to produce resistant stocks more generally useful than Northern Spy.

In both of these classic instances the use of the resistant varieties as stocks rendered it unnecessary to combine resistance and other qualities by plant breeding, and a successful conclusion was thus reached within a relatively short time. Such cases can only occur where the pest attacks the roots and where grafting is possible. A somewhat more interesting and complex instance is that of the Kieffer or Lecomte pears, which are relatively resistant to the San José Scale Insect. Here the resistance was derived from the Chinese sand pear (*Pyrus sinensis*) and the quality of the fruit from the ordinary pear (*P. communis*). It was a matter of luck that both the factors for resistance and those for quality were dominant in the hybrids, which could then be propagated by grafting, thus retaining the valuable characteristics in combination. Far more difficult has it been to secure success where the plant in question has to be propagated by seed, and as an instance the problem of the oat and the Frit Fly may be mentioned. (See Oats, and Frit Fly.) In this case certain Swedish varieties, *e.g.*, Hede, are relatively resistant, but are quite unsatisfactory in other respects, whereas most good commercial varieties of oats are highly susceptible to Frit Fly. The attempt is now being made to combine the desirable characteristics of resistance, quality, and yield, and if it had only been necessary to obtain one plant

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

which could be propagated vegetatively, the problem would already perhaps have been solved, but this is obviously not the case with a cereal, and therefore it is necessary to carry on the plant breeding so as to obtain a strain which breeds pure to the required characteristics, and it is still uncertain whether the attempt will prove successful or not.

Cultural Measures—Further space must not be devoted to the control of pests by resistant varieties, because there are other equally important methods of dealing with the crop so as to avoid damage, methods of a cultural nature. Such measures may either assist the plants to continue growing, in spite of the attack, or they may enable the attack to be avoided or dodged. The most simple instance of the first alternative is the application of top dressings of nitrate of soda or other manures yielding readily available nitrogen. Cereals which have stood the winter often meet conditions unfavourable to growth in the spring, and they are then very susceptible to injury by Wireworms or other soil pests. The top dressing enables the plants to make some growth and so repair the damage caused by the insects, until the more rapid development of later spring takes the crop out of danger. Another measure which is often combined with chemical feeding is the use of the hoe, which conserves moisture and so enables growth to continue; turnip-hoeing in the case of Flea Beetle attack is the classic instance, admittedly not a very convincing one, as the Flea Beetle too often wins. The principle, however, is sound enough, and has wide application both in tropical and temperate climates, as a crop suffering from lack of moisture cannot repair insect injury. Another common application of these cultural measures lies in the use of the roll, which assists by ensuring intimate contact between the roots and soil, but also has the effect of causing the cereal to tiller, and obviously a plant with several shoots is less likely to be destroyed by Wireworm, etc., than is a plant with but one shoot. If the first shoot of a cereal is attacked by a pest, the plant attempts to produce tillers to replace the shoot that is destroyed, but often it dies in the attempt; early rolling provides the plant with "spare" shoots.

The other line of cultural treatment already mentioned is one which enables the attacks of the pests to be avoided or dodged. When a crop is grown on the same field or on neighbouring fields for two or three years, the pests of that particular crop naturally accumulate there, and the more frequently that crop is grown, the greater the danger of injury by pests. Thus, one of the benefits derived from the rotation of crops is a reduction in the risks of loss by insect attack. This fact, of course, is elementary, but the principle behind it is worth greater attention in practice than it often receives; it is always worth remembering that, other things being equal, a crop should be sown or a plantation made at a distance from other similar crops or plantations rather than close to them, and notably in the case of perennial crops at a distance from fields from which the crop has recently been removed or the plantation grubbed up. The grubbing of an orchard, plantation, etc., removes the food supply of a large population of insects

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

which must migrate elsewhere; if they discover in the adjacent field a newly planted orchard of similar trees, they settle down at once and may cause great damage; while, on the other hand, if they have far to go before finding the new field, the fewer will survive to start trouble.

From this point of view, the extreme specialization of districts to the production of but one or two crops is certainly undesirable; admittedly it is often unavoidable, owing to conditions of climate, soil, or proximity to markets, but fashion sometimes enters into the matter also, and where there are no special reasons for starting a plantation in the immediate proximity to others precisely similar, much trouble from pests will be avoided by choosing a rather isolated position. These remarks apply to the avoidance of injury by not planting on land infested by some pest crops known to be susceptible to that pest, and by securing as much ground space as possible between crops of the same kind. Pest injury may also be reduced by securing an interval between the time when the pest becomes most abundant and that when the crop reaches its most susceptible stage. In general, the appearance of insects, whether in the adult or other stages, is at more or less definite times of the year which are only influenced to a certain degree by weather conditions, whereas it is often possible by sowing earlier or later, or by choosing a variety which is naturally earlier or later, to vary the time at which a crop reaches a susceptible stage. A very crude instance of this is the substitution of winter for spring oats in countries where Frit Fly is prevalent. The winter oat appears above ground after the last brood of flies has disappeared, and by the time the spring brood comes out it has already grown past the susceptible stage. Often, however, the timing must be more accurately worked out, as in the case of the Hessian Fly in America, which attacks autumn wheat. The wheat seeding must there be deferred until there is no risk of there being Hessian Flies about when the seedlings are through, while equally it must take place sufficiently early to enable the crop to stand the winter. The ideal time for sowing is thus confined within rather narrow limits, and it is now worked out scientifically for most winter wheat districts in America, and the farmer can sow with almost complete certainty of escaping Hessian Fly.

Sufficient reference has now been made to cultural methods of control to indicate their general scope. They are cheap as compared with measures directly aimed at the killing of the pest itself, and in the case of agriculture they are often the only method which can be afforded. Their disadvantages are, first, that they are seldom completely effective, and tend rather to reduce losses than to eliminate them; and, secondly, that their more successful use involves considerable powers of organization backed up by a store of local knowledge, since the treatment in each case has to be carefully adapted to local conditions.

Direct Measures of Control—Such measures are taken to include all those which are aimed directly at the pest responsible for injury, and

INSECTS, MEASURES OF CONTROLLING (*Continued*)—
they may be roughly divided into those which involve the use of insecticides and those which do not.

1. *The Use of Insecticides*—The nature of insecticides is discussed elsewhere, and the following notes will therefore be directed more to their use. In this connection it will be sufficient here to recall that insecticides are of three main types: internal poisons, which to be effective must be eaten by the insect; contact poisons, which kill on touching the insect; and fumigants, which "gas" the insect (the division between contact poisons and fumigants is rather artificial, as many contact poisons act by means of the gas or vapour which they give off). As regards application, insecticides may be used as liquid sprays, as dusts, as gases, and in some special manner, *e.g.*, as poisoned bait.

Liquid Sprays—Although liquid sprays are now being challenged by dry sprays or dusts, they are still the more widely used. The reasons why wet sprays have been predominant are, firstly, because most insecticides before use must be greatly diluted with some other material, of which water is usually the most cheap; and, secondly, because it is necessary to bring the insecticide into intimate contact with either the insect or the leaf, which is assisted by the "wetting" and spreading properties of water. These two advantages are likely to enable liquid sprays to retain an important place in insect control for long to come, and apart from the search for new insecticides the developments now in progress in connection with liquid spraying are, first, the introduction into spray fluids of substances which enable them to wet and spread more readily; and, secondly, the improvement of spraying machinery. The former subject is dealt with elsewhere, while, as regards the latter, the tendency is to concentrate upon machines working at a high pressure and throwing a large volume of fluid. Such machines economize in labour, tend to thorough treatment of the trees even with relatively unskilled workmen, and—no less important—get through the task more quickly than a machine working at low pressure, advantages which more than compensate for a greater waste of spray fluid. From the point of view of the present article, emphasis should perhaps be laid on the increasing importance being attributed to speed of work in spraying, owing to the realization that in dealing with most pests there is a relatively short period in which the best results can be obtained; it is, in consequence, necessary to have an equipment capable of covering the whole area to be sprayed in a few days. As regards the type of outfit in use, it is difficult to generalize, and everything depends on local circumstances. In countries with cheap and unskilled native labour, and where the crop to be treated consists of bushes or shrubs, the well-known knapsack machines are still most used, but in temperate climates power-driven machines have almost entirely replaced knapsacks, and the type most in use depends on the local factors. Where the plantations are on steep hillsides, or where they form a relatively concentrated block, there is much in principle to be said for the system in which there is a central pumping and mixing station, whence the fluid is driven along permanent pipe

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

lines, relatively short lengths of flexible piping being attached as wanted to standpipes in order to bring the wash to the spray guns. In the case of scattered plantations, the whole equipment is usually movable, and where the trees are widely spaced, as in many of the British Dominions and in the U.S.A., it is driven between the rows of trees. When this is impossible, as in most English orchards, the outfit stands on the headland, and the liquid is taken to the nozzles either by flexible piping or by a combination of semi-permanent metal mains and flexible piping.

Dust Sprays—Although as a diluent for insecticides water has the advantages already mentioned, it has certain serious disadvantages, among which is the weight of material in a liquid form which has to be transported, and in certain places the actual difficulty of obtaining a supply, or at least a supply of sufficiently pure water. The carrying of water, and where necessary the movement of pipe lines, involves considerable labour and slows down the work, while the equipment required is expensive, and the depreciation somewhat rapid. These disadvantages are at least partially overcome by using dry sprays, which consist of the insecticides mixed with, or absorbed by, some carrier which may be inert, as, for instance, kieselguhr, or may itself be of use, *e.g.*, sulphur, which acts as a fungicide and acaricide (mite killer). Transport of material is thus lessened, and since a comparatively small equipment can produce a large dust "cloud," labour is also reduced, and the speed of work is much greater than where wet sprays are used. On the other hand, dust spraying has certain rather serious disabilities, among which the chief are that dusts are somewhat less efficient in killing insects than wet sprays, and that for dormant season work (*e.g.*, for the destruction of scale insects or insect eggs) no effective dust sprays are as yet known. It is also generally stated that the climatic conditions under which dusts can be applied most satisfactorily (little wind and foliage wet with dew) occur too infrequently, and that the dusts themselves are costly. The climatic difficulty has perhaps been exaggerated, and with greater experience will probably be found not too serious, while the high cost of material, although indisputable, is more than offset by the reduction in labour costs, and this is often the case even where two dry sprays have to be applied in order to obtain the same results as one wet spray.

Dry spraying is thus a serious competitor with wet spraying in orchard and plantation practice, and there would seem to be a need for both. It is also, however, likely to prove of special interest in the case of farm and market garden (truck) crops. In these forms of cultivation, in which the foliage of the crop is often close to the ground, it is most difficult to use wet sprays satisfactorily, quite apart from their cost. Dust clouds, however, such as are thrown by a dry sprayer, drift into and under the plants in a manner no wet spray can achieve, while the large area which can be rapidly treated tends to reduce labour costs. Nicotine dusts are already being widely used in certain countries overseas, and there would appear to be a great future for similar dusts even in ordinary mixed farming if the cost of an effective

INSECTS, MEASURES OF CONTROLLING (*Continued*)—
dust can be somewhat reduced. The machinery capable of "spraying" the dust is of a relatively simple character and need not be expensive.

In connection with dusts, reference may be made to a new field which is now being exploited, the dusting of crops from airplanes. This method of using insecticides is already in practical use in connection with cotton pests in the U.S.A. and forest pests in Canada and Europe, and it has been tested in a more tentative manner in other parts of the world. The conditions at present essential to success are in the first place the devotion of large areas or at least very big fields to the crop which is to be treated; and, secondly, an environment which will permit rather low flying, and in this connection it may be pointed out that the smaller the area to be treated the lower it is necessary to fly in order to confine the application of the dust to the area in question. Finally, as the carrying capacity of the machines in use is relatively limited, a convenient landing ground where fresh supplies of dust can easily be taken on board is also necessary.

These conditions at present limit greatly the usefulness of the new method, but it should offer great possibilities if a machine can be devised capable of flying low and not too fast, and with a sufficient carrying capacity so as to render unnecessary frequent returns to ground to pick up supplies of dust.

Fumigants and Soil Fumigants—The control of insects by means of toxic gases is practically confined to cases in which the material to be treated is already confined, or can be confined, within a relatively gas-tight enclosure. It thus finds its greatest use in dealing with mills, stores, and other industrial undertakings which are outside the scope of this article. From the producer's standpoint, however, fumigation is of very great service in connection with crops grown under glass; it has a specialized use in citrus cultivation, and finds fairly general application in the treatment of insect-infested seeds and nursery stock. *Glasshouse fumigation* is a highly specialized business, and in principle the problem consists in using the fumigant in such a way as to kill the insect without destroying the plant. (See Glasshouse Crops.) Since fumigants, when diluted with air to the maximum extent compatible with toxicity to insects, are usually even then somewhat harmful to plants, the specific reactions of each kind of plant to the fumigant must be studied with a view to discovering the physiological conditions under which it is most resistant to the poison; for instance, plants should be almost suffering from lack of water when fumigated with hydrocyanic acid gas, whereas they should be thoroughly damp when treated with naphthalene vapour. A second point of principle in glasshouse fumigation is related to the length of the life history of the pest under the temperature conditions subsisting in the house. Fumigants, at concentrations harmless to plants, do not ordinarily kill all stages of the pest concerned, and therefore to obtain a practical control the treatment must be repeated at exactly the right intervals to ensure that the susceptible stages of the pest are subjected to the gas. *Citrus fumigation* is as specialized a business as glasshouse fumigation, and in addition to the insecticide problem is the serious

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

mechanical problem of the construction and movement of suitable tents which can be placed over the trees to confine the gas. For further information on this subject the reader is referred to special articles on the subject. *Seed fumigation,* and the fumigation of *nursery stock* in the dormant season, present no very serious problems, since seeds and dormant plants will withstand higher concentrations of toxic gases than plants in leaf, and the difficulties to be overcome are chiefly of a local character, and centre round the construction or improvization of a suitable fumigation chamber. For the farmer or grower who is treating small quantities a satisfactory chamber can usually be devised on the farm, but where large quantities of material, or where special difficulties are encountered in regard to penetration by the gas, a much more elaborate structure is required which, among other things, can be exhausted by means of an air pump before the gas is released, and which can afterwards be cleared of gas without danger to the operatives. This, again, is too specialized a subject to be dealt with here, and it is mentioned chiefly to emphasize a point of principle, *i.e.*, that gases diffuse but slowly into cracks and crevices, so that complete penetration in a reasonable time can often only be secured by first exhausting the air and subsequently allowing the toxic gas to replace it.

As to *soil fumigants*—that is to say, substances which when worked into the soil give off a gas toxic to insects—little can be said, because, although of all insecticides a good soil fumigant is most needed, it cannot yet be claimed that a really satisfactory article has been discovered or is even in sight. The difficulties to be overcome before a satisfactory soil insecticide can be produced are enormous. There is first the initial difficulty of discovering a chemical highly toxic to insects which will not break down too rapidly in the soil, but which equally will not injure plants. Then this substance must be produced at an economic price which is necessarily very low, and finally some method has to be found of working the insecticide into the soil so as to secure uniform penetration by the gas given off, a very serious difficulty in many soils. For these reasons the use of soil fumigants is limited to special cases, such as where the value of each individual plant in the crop is high, *e.g.*, sugar cane and fruit trees; where, as in glasshouse work, small bulks of soil only are concerned; and on golf greens and pleasure grounds where the question of cost is of secondary importance. Soil fumigants have already and are likely to have a more extended use as deterrents, as, for instance, the application of naphthalene dressing for preventing vegetable root flies from laying their eggs on vegetable crops.

Baits—Lastly, brief reference must be made to the destruction of insects by poison baits, a method which entails the use of some internal poison insecticide distributed in a substance which is not the ordinary food of the insect. In the case of many pests which live at ground level and attack low-growing crops, the application of an internal poison insecticide to the crop may be either impossible or ineffective, but when such insects are prepared to eat some cheap material, *e.g.*,

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

bran, as readily as their own food, it is quite feasible to poison the bran with Paris green and scatter it about where the pests are present. With suitable variations in the bait to meet the tastes of the insect concerned, this is one of the standard methods of dealing with Cutworm Caterpillars, Leather Jackets (*Tipulid* larvæ), and Grasshoppers or Locusts. Another form of poisoned bait is used against fruit flies (*e.g.*, the Apple and Cherry Fruit Flies), the arsenical insecticide being sprayed on to the foliage either in a water mixture or in some supposedly more attractive liquid, such as sugar syrup. The flies thus feed upon the poison, and die before laying their eggs. It is quite possible that the bait method of dealing with insect pests may develop greatly, a development which depends, however, on an increase in knowledge of the senses of insects and notably their responses to odours.

2. *Other Direct Measures of Attack*—Apart from the use of insecticides, there are a great many different methods in use for destroying insects, but they are of a somewhat miscellaneous character and not easily classified. The simplest are of a purely mechanical or cultural character; where cheap labour is available, for instance, it may be more economical to collect a pest of large size by hand than to spray against it; then, again, waste material or material of little value infested by pests may be burned, or in some cases be ploughed in. The noted Cornborer Moth (*Pyrausta nubilalis*), for instance, is found in the corn (maize) stubble after the crop is carried, and the complete destruction or burning of this stubble would seem likely to go far towards dealing with the pest. The details vary in every case, but it may be regarded as a general principle that the clearing up of waste plant material—dead trees, prunings, or "slash" from tree-felling—is of great importance by directly killing an incalculable number of insect pests.

As regards more specialized methods of control in this section, trapping is the most important. The trap may consist of a sticky barrier over which the pest must pass to reach its objective—the tanglefoot or grease-band placed on fruit trees to catch the wingless females of certain moths is a good instance—or it may consist of some material specially attractive to the pest when hibernating or when about to pupate, as, for instance, the sack or corrugated card bands used for Codling Moth. In the latter case, the traps must be removed and burned, or the pests in them destroyed in some other way. Natural traps working on the same principle are used in forestry when the bark of felled trees or other worthless material—branches, wood, etc.—is allowed to become infested and is then burned, or, as in England in the case of the Pine Weevil (*Hylobius abietis*), the traps may be visited and the pests may be caught by hand (see Insect Pests, under Fruit). As alternative to allowing the insect to find the trap, the latter may be brought to the insect; in the simplest case, sticky tarred sacks are dragged over crops affected by Flea Beetles, which jump up and stick to the tar, and this crude form of apparatus has been developed in various ways to form the Grasshopper or aphid "dozers" used in the U.S.A., in which the insects are

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

brushed or collected into a bag, and experimentally an apparatus has been devised which works on the vacuum cleaner plan. In general, it cannot be said that these various forms of apparatus are as effective as treatment by insecticides, although in the hands of an enthusiast they do good work. The stationary forms of trap have, however, a very definite use, which is not unlikely to be further developed if future researches on the senses of insects should enable the latter to be attracted to a given spot. In this connection scent, or the sense of smell, seems to offer the greatest possibilities, and as an instance the fact that the Japanese Beetle (*Popilia japonica*) is strongly attracted to geraniol may be mentioned. Light is obviously an alternative possibility as an attracting agent, but although used in the French and Swiss vineyards, its results are perhaps more spectacular than useful, large numbers of harmless insects being attracted and destroyed; while in the case of most species, pests or otherwise, the greater part of the "bag" often consists of males.

Natural Enemies—The last method by which it should be possible in theory to control insect pests is by helping their natural enemies, a subject which, so far as insecticides are concerned, is fully discussed in an article entitled "Beneficial Insects," to which the reader is referred. The following brief notes may, however, be added.

Birds and other Vertebrate Enemies—While certain insectivorous birds may specialize in the insects upon which they feed, most take a wide range of insect food, which includes both pests and other insects. Naturally a bird tends to eat more of the insects which are easy to get—that is to say, the common insects, and to this extent their attention is directed to the pest, but since practically everywhere insects which are not pests are in the majority, birds can only be relied upon to a limited extent, and the greatest encouragement given to birds would be unlikely to bring about the complete control of any one pest. Regarding them, however, as useful allies, specially in cases where artificial measures of control are inadequate, something may be done for their encouragement. Such well-known measures as the provision of nesting boxes and additional food supplies in hard weather are too familiar to need further reference; they may be of real importance in the cultivation of small areas (gardens, small orchards, etc.), and the former, perhaps, in certain types of forestry, but their general effect cannot be wide. More important, if it were feasible, would be the provision of small areas of the types of country (from the ecological standpoint) which birds prefer—rough, open scrub; small coverts, etc. The tendency in modern agriculture is to reduce hedgerows to the maximum extent, to clear up waste pieces of land, and so forth, and no one could advise on account of birds the adoption of a slovenly type of farming, but the deliberate establishment of small bird "sanctuaries" of small size (quarter acre or so) properly fenced might prove well worth while. A second measure which will tend to keep birds distributed in hot dry weather is the provision of water here and there in places accessible to them (which water troughs for

INSECTS, MEASURES OF CONTROLLING (*Continued*)—

stock often are not). Finally, with reference to birds, it should perhaps be mentioned that great care is necessary in the encouragement of gregarious species. The operations of a species which feeds in flocks are naturally concentrated on small areas of ground, and therefore, in so far as they feed upon pests, their work is more effective, but as against this the more accessible insects are speedily taken, and the birds may then be driven to adopt a vegetarian diet. In such cases, then, a certain number of the species of bird may be wholly beneficial, whereas any increase will cause it to become a pest.

Insect Enemies—In the article previously referred to, it is pointed out that as yet little can be done to increase the numbers of an insect parasite already present in a country, and that the chief application of the method is when a new pest arrives in a country but leaves behind the enemies which attacked it in its original home. Under such circumstances the introduction of the enemies may result in the reduction of the pest to a position of no agricultural importance, but this happy result is only likely under special circumstances. The more probable result is that a sort of balance will be established between the pest and the parasites, so that while excessive multiplication of the former will not go on continually, nevertheless the pest will never be reduced to complete subjection. Under these circumstances, artificial measures of control will probably still be needed, and the advantage, the very great advantage, resulting from the introduction of the natural enemy will be that the pest is reduced to a position which enables artificial measures to secure whatever further reduction is necessary in order to safeguard the crop from destruction.

Diseases—Claims are not infrequently made that by a distribution of cultures of fungal or bacterial diseases insect pests may be controlled, instances being in the case of Locusts and Cockchafers. In general, these claims have not proved to be well founded. The spread of disease among insect pests appears to depend too greatly on suitable climatic conditions to encourage much hope of success in the future, and the only condition where practical results can be obtained is in the case of a pest which during a certain season—the wet season, for instance—normally falls a victim to a disease, whereas in the other seasons it is unaffected. It may then be possible to distribute the disease—a fungus, for instance—as soon as favourable climatic conditions set in, and so secure a more rapid destruction of the pest than would have been the case if the disease had been allowed to spread naturally. Such cases are, however, quite special, and are at present merely exceptions to the rule that no deliberate use can be made of the diseases to which insects are subject, and that we must remain satisfied with the very great good which such diseases do without our assistance.

J. C. F. F.

INTERNAL COMBUSTION ENGINES—This name has been given collectively to all those engines in which the combustion of the fuel, whatever it may be, takes place actually inside the cylinder in which the piston operates. Hence, it includes gas engines, oil engines, and

INTERNAL COMBUSTION ENGINES (*Continued*)—

petrol engines, and heavy oil engines of the Diesel and semi-Diesel types.

In all such engines, without distinction of type, the following series of operations takes place: (1) A charge of fuel, and air sufficient to ensure its combustion, is drawn into the cylinder and compressed; (2) the mixture is fired and combustion takes place; (3) the spent gases are expelled from the cylinder. The different types are distinguished by the way in which these operations are brought about.

In practically all modern engines the cycle of operations indicated is carried out either by four piston strokes (Otto cycle) or by two (Day cycle); others, such as the Clerk cycle (two-stroke) and six-stroke cycle are used occasionally, but particulars must be sought elsewhere. In the four-stroke cycle, which is by far the more common, a movement of the piston away from the head of the cylinder causes the space

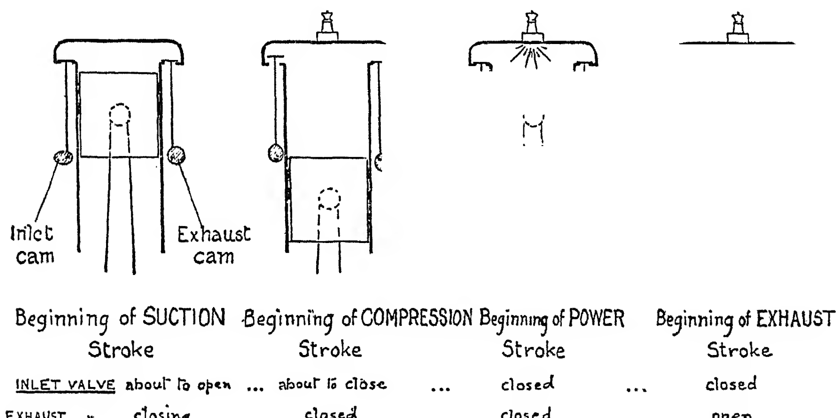


FIG. 9.—OPERATION OF FOUR-STROKE ENGINE (OTTO CYCLE).

between them to be filled with the explosive mixture which usually enters the cylinder ready mixed by way of an inlet valve from an apparatus to be described shortly. The inlet valve then shuts and the return stroke of the piston compresses the gas in the cylinder, and, just as the piston moves away on its outward stroke for the second time, the compressed fuel mixture is exploded by a spark from a sparking plug or otherwise. This is the power-stroke, pressure of the explosion in the cylinder communicating its energy to the piston. On the second return stroke an exhaust valve opens, and the burnt gases are expelled from the cylinder by the piston. The process is then repeated indefinitely. It is clear that in this case two revolutions of the crank shaft are required to complete the cycle of operations with four strokes of the piston—namely, the suction stroke, the compression stroke, the power stroke, and the exhaust stroke. There are thus three strokes in which energy is used for one in which a new supply is

INTERNAL COMBUSTION ENGINES (*Continued*)—

obtained from the fuel, and hence, in order that such an engine (if of a single cylinder) may continue running, a heavy fly wheel must be fitted to carry the process through as far as the next power stroke; indeed, it is not unusual to fit such an engine with two fly wheels. Fig. 9 shows the above sequence of operations in a four-stroke engine.

In the two-stroke cycle, which is frequently used for engines of small size, and in hot-bulb ignition semi-Diesels, such as the Allen, Petter, Tangye *et al*, the piston near the extremity of its outward excursion uncovers two ports, one communicating with the outer air by way of a silencer through which the exhaust gases pass out, and the other, which opens a little later, communicating with the crank case or a subsidiary cylinder in which the fuel mixture for the next change has already been partly compressed by the outward movement of the piston. This mixture then enters the cylinder, and is compressed and fired at the end of the return stroke. This sequence is illustrated in Fig. 10. On the up stroke of the piston the fuel mixture is drawn into the crank case through a valve at A which shuts as soon as the down stroke commences, so that the mixture is partly compressed in the crank case. As the piston nears the end of its down stroke the exhaust port B is exposed, and shortly afterwards the inlet port C, when the compressed mixture in the crank case passes up into the cylinder head by the communicating passage D, and, being deflected upward by the lug E on the piston, tends to wash out the residual exhaust gas in the cylinder. On the up stroke of the piston the mixture is again compressed in the cylinder and then fired.

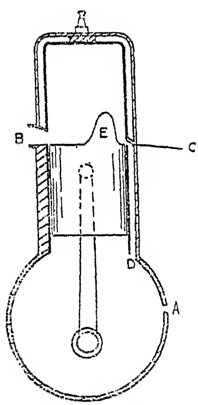


FIG. 10.—TWO-STROKE ENGINE (DAY CYCLE).

In this type of engine every other stroke is clearly a power stroke, so that it might be thought that, other things being equal, this type would have about double the efficiency. In practice it is found that there is but little to choose between them on this score, for the following reasons: in the four-stroke the cylinder is being charged during rather more than 180° of crank-shaft revolution, the exact angle depending on the valve setting; while in the two-stroke this only takes place over about 80°. The discharge again takes place over 180° of crank-shaft turn, or rather longer in the four-stroke, while in the two-stroke it can only take place while the exhaust port is open, so that far more of the spent gases always remain to mix with the fresh mixture. The two-stroke engine is also less economical of fuel than the four-stroke, since some of the fuel mixture always escapes with the exhaust gases in the process of charging. Two-stroke engines also generally require more efficient silencers than four-strokes, as the opening of the port is rather more sudden than that of a valve, and the exhaust escapes with explosive violence.

The explanation of the two types of internal combustion engine applies generally to all types. In the gas engine the fuel mixture is

INTERNAL COMBUSTION ENGINES (*Continued*)—

compounded of some kind of inflammable gas and air; coal gas, producer gas, coke oven and blast furnace gases, and natural gas have all been used with success. Coal gas is usually too costly, and the remaining gases mentioned are normally unobtainable by the British farmer. In case blast furnace gas is to be used, it should be mixed with much less air than in the other cases. In ordinary oil and petrol engines a mixture of air and the vapour of the liquid fuel is made in an apparatus known as a carburettor, the principle of which is illustrated in Fig. 11. No attempt is made here to illustrate or discuss the different types of carburettor which have been made and are in general use—a considerable number of types are described by A. A. Potter in "Farm Motors," p. 78 *et seq.*, New York (McGraw-Hill), 1913. The type shown in Fig. 11 is fitted to many small engines, and it will be seen that in principle a carburettor does not differ from an ordinary scent spray. Air travelling with considerable velocity passes over the fine spray nozzle, the tube from which is kept filled with the fuel from the tank below by means of a small ball valve at the foot of the tube. By this means the liquid is drawn out from the jet and blown into the form of spray which rapidly volatilizes, yielding a mixture of air and the vapour of the fuel. In cases where paraffin is used instead of petrol, the warmth of the inlet manifolds may be insufficient to volatilize the fuel spray completely, and in this case the inlet manifold, or in many cases the jet portion of the carburettor itself, may be jacketed with a flue through which a portion of the exhaust gases is discharged. Several such carburettors are described by Potter (*loc. cit.*). In Diesel and semi-Diesel engines a carburettor is dispensed with, and the fuel is injected directly into the cylinder or a small compartment in connection therewith. In engines intended for use in dusty work, whether on tractors or otherwise, some sort of air purifier should be attached to the air inlet; a number of forms of purifier used in practice will be found described in A. F. Collins' "Farm and Garden Tractors," pp. 66-69, New York (F. A. Stokes Company), 1920.

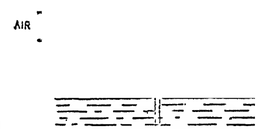


FIG. 11.—SUCTION FEED CARBURETTOR.

Ignition of the charge in all forms of internal combustion motors except Diesel and semi-Diesel types is nowadays accomplished by means of an electric spark passed between the points of some form of sparking plug. Although many varieties of such are on the market they differ but little in construction: a central metallic rod, at the outer end of which is a terminal, comes down between some projecting points on the metal part which is screwed into the cylinder. The central rod is insulated from the outer metal body by porcelain or other insulating material. Now when the plug is screwed into place in the cylinder its outer metal covering and the cylinder being in conducting connection with each other and the frame of the engine must be at the same potential as this. If now the central rod which

INTERNAL COMBUSTION ENGINES (*Continued*)—

is insulated from these by the porcelain is by some means raised to a potential sufficiently high to break down the insulation of the layer of air or compressed gas between the end of the rod and the points, a spark will pass and the charge will be ignited. The means adopted to secure this breakdown difference of potential at the right moment for firing the mixture are numerous; induction coils, low tension inductor, and armature magnetos and high tension magnetos are all used. In all these there is embodied in some way the principle of electro-magnetic induction. A simple example of this is a ring of iron, one side of which is wrapped with (say) 10 coils of insulated wire, and the other side with 100 coils quite separate and unconnected in any way with the first lot. Suppose now that current from a battery be switched on through the first lot in such a way that the potential difference between the ends of the 10 coils is 1 volt, then at the moment of closing the switch a momentary potential difference of $1 \times \frac{100}{10}$, *i.e.*, 10 volts, will be induced between the ends of the wires of the second lot of coils due to the creation of a magnetic field in the iron of the ring by the current in the first set. This is the basic principle on which induction coils and magnetos work—that is to say, they are so arranged that a small voltage generated in some manner in a primary circuit shall be enormously multiplied at the ends of a secondary coil of many turns, one end of which is connected to the frame of the engine and the other to the terminal of the sparking plug. Space does not permit of a further description of these pieces of apparatus; further details may be sought in Potter's book already cited, pp. 91 *et seq.*, and in that of Collins, pp. 72 *et seq.*, or in one of the ordinary manuals on magnetos and induction coils, such as F. R. Jones' "Electric Ignition," New York (Wiley), 1912.

It is clearly essential that the spark should pass between the points inside the cylinder at the critical moment—that is, at or rather before the beginning of the power stroke. To secure this, what is called a distributor is employed, which consists of a revolving contact arm connected to the magneto which moves over a number of studs connected to the sparking plugs of the cylinders. This is so arranged that at the moment the contact arm comes on to one of the studs the interrupter of the magneto breaks the current in the primary circuit, thus inducing a very high voltage on the secondary and causing the spark to pass in the cylinder to which the particular stud is connected.

In semi-Diesel engines there is a hot bolt or hot tube which, together with the compression of the mixture, is sufficient to cause ignition. In starting up, this bolt or tube in the cylinder head has to be artificially heated, but later this may be discontinued, as the heat generated by the explosion of successive changes will be sufficient to keep it hot. In Diesel engines where the compression ratio is higher than in semi-Diesels the heat of compression alone is enough to ignite the successive charges. Such engines are often started by compressed air. The Diesel engine is particularly good in large sizes, and a nine-cylinder two-stroke Diesel engine lately erected by the Hamburg

INTERNAL COMBUSTION ENGINES (*Continued*)—

Electricitätswerke develops 15,000 horse power. The semi-Diesel engine has the advantage that extremely high compression with its concomitant stronger design and arrangements for high pressure injection air blast are avoided.

It has been mentioned that in the four-stroke engine only one impulse is given to the fly wheel for every two revolutions of the crank shaft. Smoother running may be attained without forsaking the four-stroke principle by having a number of cylinders with pistons operating on the same crank shaft and disposing the impulses symmetrically. A common arrangement in motor-car engines is to have four cylinders, two beginning the power stroke, while the other two are beginning the suction stroke. In aeroplane engines a radial arrangement of the cylinders round the crank shaft is more usual.

The temperature generated inside the cylinders is, as will be appreciated, very high, and some method of cooling has to be adopted to prevent the cylinder head becoming red hot and inducing the combustion of the charge before compression is complete (pre-ignition), causing considerable loss of power, to say nothing of abnormal wear on the engine. In small engines air cooling is sometimes used, the cylinder being provided with fins which assist the loss of heat to the surrounding air, as in most motor-cycle engines; but more usually a water jacket is provided round the cylinder, as shown in the two-stroke cylinder (Fig. 10). The water passes into the surrounding jacket at the lowest point and out at the highest, returning by way of a radiator in which, in passing through some form of metal tube meshwork, it is cooled by a stream of cold air drawn over the outside of the metal tubes, which may or may not be provided with fins.

The engine described and shown in Fig. 9 is provided with a type of valve which is common and known as the "poppet" valve. It is important that such a valve should fit well on its seating, and they have therefore to be re-ground periodically, especially the exhaust valve, which becomes pitted by the high temperature gases of the exhaust. They are operated by suitably shaped cams keyed to a shaft revolving at half the speed of the crank shaft. Another type of valve altogether, known as a "sleeve" valve, is made, and has the merit of making the engine extremely silent in running. In these engines the sides of the cylinder are provided with ports for inlet and exhaust, which are open and shut at the proper times by two concentric reciprocating sleeves working between the cylinder wall and the piston, and operated by eccentric cams set out of phase with one another, and keyed to a shaft rotating at half the velocity of the crank shaft from which it is operated by a chain transmission. Elementary descriptions of these engines commonly fail to make the operation of such a valve system at all clear to the lay mind, and Fig. 12 has been prepared in the hope that it may prove useful in this regard. To give the proper idea twelve separate small sketches are given of the same engine cylinder for every 60° of revolution of the crank shaft over two complete revolutions. The valve timings are made to accord approximately with those in Fig. 9. It will be noticed that the cylinder head has to be of special design to

INTERNAL COMBUSTION ENGINES (*Continued*)—

accommodate a "junk ring," not shown in the sketches, around an intruded portion of the head. In this way a gas-tight junction between the inner sleeve and the cylinder head is provided. The sketches will be found to be more or less self-explanatory.

Internal combustion engines may be lubricated by splash lubrication from a sump into which the big ends dip at each revolution, but it is becoming more and more the custom to provide some system of forced lubrication, in which case the oil is forced along guide channels in the shaft, etc., to all bearings where it is required.

The frame of an engine should be of such design that the stresses on the power stroke do not work bolts, nuts, etc., loose.

Most engines in use on the farm are provided with governors usually of the centrifugal type which operate on the fuel supply, cutting this down as the revolutions increase.

Starting up from cold is always a difficult business, especially when, as in so many forms of farm tractor, this has to be done by hand. In these cases the magneto is usually provided with an impulse starter which gives the armature a good speed in starting, and so ensures a hot spark when the handle is turned. Electric starters which are sometimes fitted have a subsidiary pinion run by an electric motor operated from the cells. This pinion can be pushed in so as to engage with a sprocket on the engine shaft, and so turn the motor over, but the wear on these prockets and pinions is considerable when they are used in starting up from cold. Another method is the injection of compressed air and fuel into the cylinders and then firing this, but this naturally involves an appreciable amount of extra apparatus. A new type of cold starter for crude oil engines, such as semi-Diesels, was introduced in 1923 by Messrs. Petter. It consists of a hot cartridge which is lit and introduced into the cylinder head by a plug; the heat evolved while the cartridge burns is sufficient to fire the first few charges of fuel, and the engine is then able to continue firing and the working temperature is soon attained. These cartridges, which are inexpensive, are described with a figure showing the mode of use in the *J.R.A.S.E.*, lxxxiv., 251, 1923.

An interesting and novel form of internal combustion engine has been developed in recent years, since the production of the Michell thrust block, which permits of the lubrication of surfaces pressed into intimate contact under high pressure. The piston rods in these engines operate on the surface of a lubricated "swash plate" fixed to the main shaft in a plane at an angle of about 45° to the shaft. As the plate receives the piston pressure, it slips from under the piston rod and rotates the shaft, the further rotation being effected by the next cylinder piston which impinges on the swash plate further round the periphery.

The efficiency of these engines, as of all heat engines, consists of two factors, the mechanical efficiency and the thermodynamic efficiency. The former has the same meaning as in other branches of mechanical science, and represents the percentage of the energy supplied which can be realized as work; when losses due to friction, impact, heat loss, etc., are subtracted it may be 85 or 90 per cent. All heat engines,

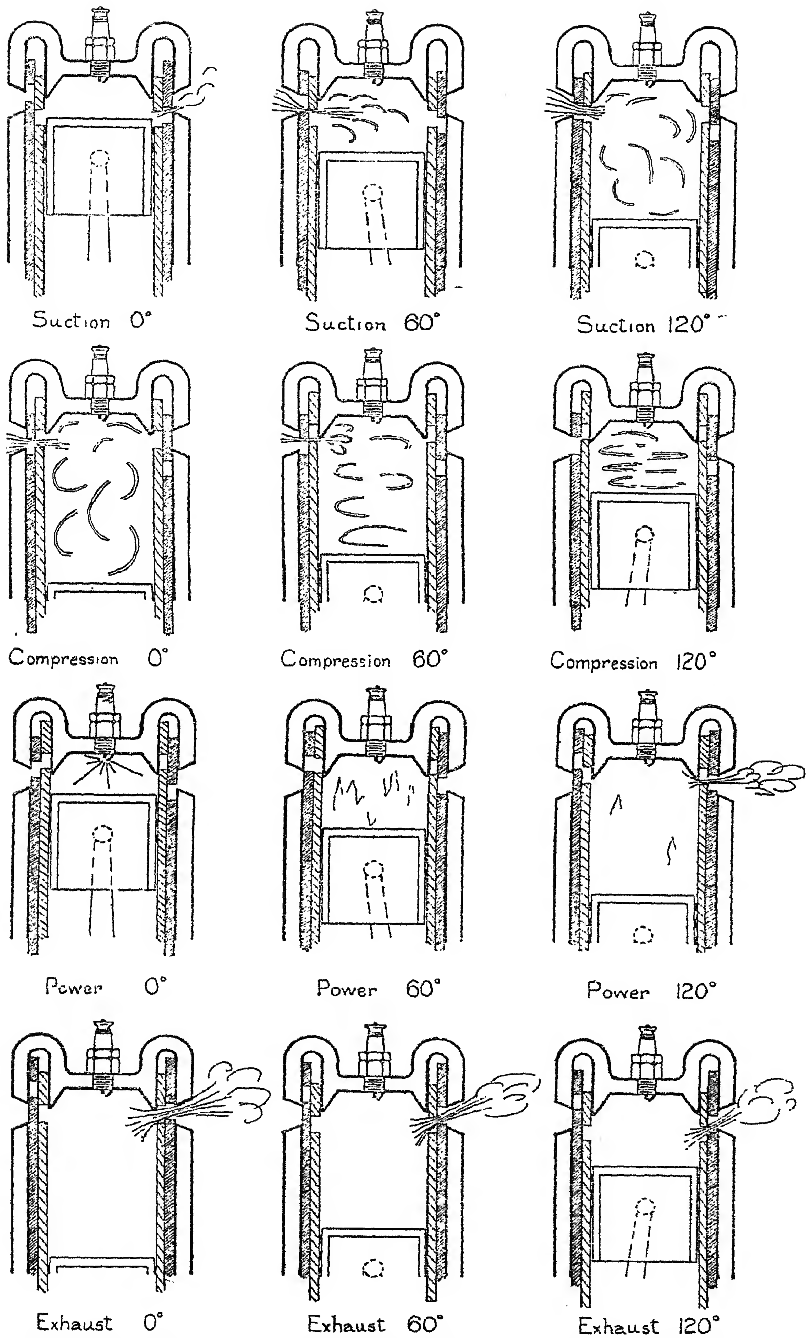


FIG. 12.—SIMPLIFIED SCHEME OF SLEEVE VALVE ENGINE OPERATING ON OTTO CYCLE, ASSUMING PHASE DIFFERENCE OF SLEEVE ECCENTRICS 90°.

INTERNAL COMBUSTION ENGINES (*Continued*)—

however, are subject to a further loss in efficiency due to the impossibility of arranging that the heat drop shall be from the working temperature to the absolute zero. This loss is particularly serious in steam engines. In internal combustion engines the working temperature is much higher, and the heat drop from working to exhaust temperature can be made a greater fraction of the absolute temperature. Hence it has been found possible to attain a relative brake thermal efficiency of more than 50 per cent. in some engines of the Diesel type in which the compression is high, whereas that of a compound steam engine rarely exceeds 20 per cent.

A more complete elementary account of these engines, more especially in their application to farm work, will be found in A. A. Potter, "Farm Motors," McGraw-Hill, New York, 1913; A. F. Collins, "Farm and Garden Tractors," F. A. Stokes, New York, 1920; and X. W. Putnam, "The Petrol Engine on the Farm," Page, London, 1921. For more advanced treatment see H. R. Ricardo, "The Internal Combustion Engine," 1923, and A. B. Chalkley, "Diesel Engines," 6th edit., Constable, London, 1927; also Society of Motor Manufacturers and Traders, "Report on the Tractor Trials held at Lincoln," London, 1919, 1920; H. E. Wimperis, "The Internal Combustion Engine," Constable, London, 1922; G. J. Wells and A. T. Wallis-Taylor, "The Diesel Engine," Crosby Lockwood, London, 1924. T. D.

IODINE (Symbol I; atomic weight 126·932; atomic number 53)—A black, crystalline element of some importance in the form of its compounds, the iodides and iodates which occur to some extent in Chili saltpetre and in kelp (*q.v.*). Iodine is found universally in minute amounts in plants, and the amount appears to depend largely on the composition of the soil in which they are grown (see J. B. Orr, "Minerals in Pastures," Lewis, London, p. 23, 1929). Its presence in minimal quantity has been supposed necessary to the proper functioning of the plant cell, in which the call for iodine appears to be nuclear. Iodine is essential to the well-being of animals, in which it is the thyroid gland from which the demand chiefly emanates. Certain types of goitre yield to iodine treatment, but as there are other types in which its use is distinctly dangerous, expert opinion should be obtained before experimenting with it in cases where pigs or other animals show a goitrous tendency (see Metabolism, Mineral). The iodides and iodates are used largely in medicine and veterinary medicine, and the compound iodoform (CHI_3) is an important surgical antiseptic.

IRISH FREE STATE, Agriculture of—See Agriculture.

IRON (Symbol Fe; atomic weight 55·84; atomic number 26)—Although occurring in plants and animals in very small quantity, this element is, nevertheless, essential to the most fundamental life processes. Considerable difference of opinion has existed for a long time as to whether animals suffering from iron deficiency are able to take up inorganic iron supplied in medicines. While this may be considered to have

IRON (*Continued*)—

been settled in the affirmative, more especially when it is presented in the form of the double citrate of iron and ammonium, there are nevertheless, among human beings at all events, those who are apparently exceptions to this rule and only benefited by hæmoglobin or other complicated organic iron compounds, such as occur in meat, spinach, eggs, etc. The normal excretion of iron is by the intestines.

In plants the action of iron is not properly understood; it is absent from chlorophyll, but is present in the colourless stroma of the chloroplast, and was thought by Moore (*Proc. Roy. Soc.*, B. 87, 556, 1914) to have a catalytic action on the oxidations resulting in the destruction of leucophyll. Later investigations by Wurmser ("Recherches sur l'assimilation chlorophyllienne," 1921) tend to show that it may have a direct function in the process of photosynthesis. Lack of iron in the soil produces a *chlorosis* quite distinct from etiolation, since form is unaffected. On the other hand, iron is not invariably beneficial, and ferrous iron is invariably toxic to plant life. The red, yellow, green, and blue colours assumed by clays are due almost always to the presence of some form of iron in them.

KAINIT—See Fertilizers.

KALE, MARROW-STEM—It is indeed strange that such a valuable crop as marrow-stem kale has taken so long to establish itself as an important fallow and fodder crop in British farming. Marrow-stem is a "variety-hybrid," and is a result of crossing kohl rabi and thousand-headed kale. (See Brassicæ, Morphology and Genetics of; and Fig. 2, Plate V.) The great merits of the crop are the enormous quantity of greenstuff it produces, its low cost of production, and its effectiveness as a cleaning crop.

Fortunately these merits are being recognized fairly rapidly, and marrow-stem kale is gradually replacing a large portion of the acreage under turnips, swedes, and mangolds in eastern England.

Varieties—There are two main varieties: Green-stemmed and Purple-stemmed; the former is by far the more popular variety, though in some parts of England the latter has a reputation of being more resistant to frost.

Cultivations—Marrow-stem kale will thrive on a wide range of soils, and may be relied upon to give satisfactory yields on any soil which will produce crops of turnips, swedes, or mangolds. The main essentials are that the soil should not be waterlogged, or deficient in lime.

The cultivations for the crop are practically the same as for other root crops which are sown in rows and singled. Ploughing and all other cultivations should be deep and thorough, and as it is best to drill the crop early in spring, it is advisable to do all the possible cleaning operations in the autumn.

Seeding—Marrow-stem kale may be transplanted like thousand-headed kale, but it is more usual to sow seed and cultivate like an ordinary root crop. The seed may be sown, according to soil and

KALE, MARROW-STEM (*Continued*)—

climatic conditions, as early as the end of March. This time of sowing is becoming increasingly popular in East Anglia to provide greenstuff, instead of maize, for cows in August. Seeding, however, may be carried out any time from the end of March to the end of June, but seeding as early as possible is generally recommended to reduce the risk of loss from the Turnip Fly.

The seed rate required is from 3 to 4 lbs. per acre, and the seed may be sown either on the flat or on ridges, varying from 20 to 30 ins. in width.

The crop is horse-hoed, preferably with a double disc horse-hoe, as soon as the plants appear above ground, and may be followed by another horse-hoeing before singling.

Careful singling of the plants is not universally popular, and indeed the modern tendency is more to thin than single. However, where the crop is grown for dairy cows it is more or less customary to single the plants to about 8 ins. apart. On the other hand, if the crop is to be folded or cut for sheep, it is more usual simply to chop out or thin the plants and not to make any attempt at accurate singling. If the crop is "well done" and singled to, say, a width of 10 to 12 ins. between plants, the stems tend to grow coarse and are then not relished by stock. It is in the main, therefore, better to keep the plants rather close together, and so avoid excessive stem growth.

Cultivations after thinning and singling are the same as for swedes. Horse-hoeing is practised so long as it is possible to get between the rows, and until the leaves cover the ground.

Manuring—Where possible farmyard manure should be applied for marrow-stem kale in as great quantity as circumstances will permit. The requirements of artificial manures are exactly the same as for thousand-headed kale (*q.v.*). The crop is a gross feeder, and in addition to receiving a fair dressing of phosphates and potash, applications of nitrogenous manures should be generous and liberal.

The whole of the nitrogen may be applied before seeding, though it is not unusual to apply only half then and the other half as a top dressing after singling.

Feeding—All classes of farm livestock eat the crop with relish, but in the main it is grown either for cutting green for milk cows or for folding with sheep. When grown for cows, the plants are usually fairly carefully singled and cut by hand when ready to feed. If the stems are very thick they may be split so that stock may eat them the more readily.

Where the crop is produced for folding, the plants should be grown close together to avoid coarseness in the stem and to produce as much leaf as possible.

The average yield of marrow-stem kale is 30 tons, giving 54 cwts. starch equivalent per acre. This is practically three times the feeding value per acre of an average crop of swedes, and it is therefore necessary to bear this in mind when deciding upon the size of fold to be allowed

KALE, MARROW-STEM (*Continued*)—

for a given number of sheep, or upon the quantity to be fed to dairy cows. (For Composition and Feeding Value see also Feeding Stuffs.)

J. C. L.

KALE, THOUSAND-HEADED—Thousand-headed kale has been cultivated as a fodder crop for very many years, but was introduced first to general notice in 1876 by a farmer named Robert Russell. According to Malden and Nisbet ("Farm Crops," vol. ii., Gresham Publishing Co.), it arose as a selection from the Tree-cabbage or Jersey Kale, which rises several feet high and is grown mainly for its sprouts. (See Brassicæ, Morphology and Genetics of; and Fig. 2, Plate IV.)

The crop is cultivated largely for folding sheep, and is only rarely cut as green food for other stock.

Seed Bed—Thousand-headed kale is a fallow crop, and must be subjected, therefore, to all the cultivations commonly associated with root crops, which may be summarized as deep ploughing, and deep thorough cultivations before seeding, resulting in a fine tilth and a firm seed bed.

Seeding—Thousand-headed kale is more resistant to frost than marrow-stem kale (*q.v.*), and, therefore, is usually cultivated to provide green food for sheep during the first three months of the year. For this purpose the seed may be sown as late as July, and may be broadcast or sown in ridges as for swedes and turnips. More usually, however, the seed is sown in specially prepared beds at the rate of 2 lbs. per pole, and the young kale plants are transplanted in August into land that has previously grown a crop of tares or some similar crop that has been folded off by the end of June.

The width left between the plants varies according to the purpose for which the crop is to be used, from 1 to 2 ft. on the square, the normal being 18 ins.

The advantages of transplanting as compared with ordinary seeding are economy of seed and a lessening of the risk of Turnip Fly attack.

Seed may also be drilled as early as March or April, and the resulting crop may be ready for folding during the autumn; 4 to 5 lbs. per acre of seed are then required, and the width between the rows is the same as for turnips. The plants are subsequently singled to a distance of from 9 to 12 ins., according to the width of row.

Manuring—Kale is a gross feeder, and requires liberal applications of artificial manures, particularly those containing nitrogen. An average dressing is 3 to 5 cwts. superphosphate, 1 cwt. muriate of potash, and 2 to 3 cwts. per acre of sulphate of ammonia.

Applications of a nitrogenous manure like sulphate of ammonia should be liberal, as the crop responds readily to such treatment, and produces a large amount of leaf which, in addition to providing valuable feed for stock, has a most important smothering effect on weeds.

Cultivation—The crop can be grown either on the flat or in ridges, but is usually grown on the flat. The cultivations after the crop is in

KALE, THOUSAND-HEADED (*Continued*)—
are just the same as for swedes or other crops where drilling and singling are practised. Horse-hoes should be kept going as long as it is possible to get between the rows, and until the ground is well covered by the leaves.

Feeding—Thousand-headed kale can be kept productive for at least two years, but this is unusual. It is, however, like rape, more than a one-feed crop, and provided it is not eaten down too hard or cut too close to the ground, it recovers fairly quickly and provides food for further folding or cutting.

As already indicated, the seed may be sown any time between March and July, and the crop can be made to be available at almost any season of the year. The main use of thousand-headed kale, however, is to provide green food for ewes and lambs in the early part of the year, and these are usually folded on it, although the crop may be cut by hand and fed to sheep on grass.

The average yield of greenstuff is usually regarded as just over 20 tons per acre, which, converted into cwts. of starch equivalent per acre, gives a figure of 37. Comparing it with the 19 cwts. per acre of starch equivalent obtained from an average crop of swedes, there is a substantial margin in favour of the kale.

J. C. L.

KAOLIN (**China Clay**)—The name is a corruption of Kau-ling, a hill east of King-te-chen, whence the first samples were brought to Europe. The chief constituent of kaolin is kaolinite (Al_2O_3; $2SiO_2.2H_2O$), a decomposition product of many aluminium silicates, but in the case of china clay almost exclusively of orthoclase felspar in granite. This is the case in the Cornwall and Devon deposits. China clay of the best quality is said to consist of two types of ingredient, named respectively china clay and china stone. The former gives the necessary plasticity and retention of form; the latter, melting at the furnace temperature, imparts the glaze and the much prized translucence of porcelain. Kaolin is used also as a pigment for mixing with graphite in the making of lead pencils, and as a filler for paper and textiles.

KELP—Dried seaweeds or the ashes of burnt Scottish seaweeds, containing chiefly the carbonate, sulphate, and sulphide of sodium, together with other substances normally present in sea-water. The insoluble portion consists mainly of calcium carbonate, silica, and alumina. Kelp is used to a considerable extent in the north-west of Scotland as a manure, and also both in Scotland and Ireland as a preservative covering for potatoes. From the manurial point of view the burning process is bad, since the large nitrogen content of the seaweeds goes entirely to waste, as do other valuable soil-ameliorating qualities inherent in vegetable refuse in general. It was at one time common to extract alkalies and iodine from kelp; in fact, it was the source from which the discoverer Courtois first obtained the latter element, which is present to the extent of about 8 lbs. per ton. A similar substance is prepared in Normandy and Brittany under the name *varec* or *vriac*.

KELP (*Continued*)—

The composition of kelp is very variable owing to the exceptionally variable composition of the seaweeds involved. Of late years kelp has been used in other industries as a source of oil, creosote (*q.v.*), ammonia, etc. It has recently been suggested as a suitable source of iodine for use in regions where goitre is rampant, it being thought possible that the administration of this element by means of some natural vegetable carrier might easily prove more beneficial than the usual inorganic salts.

Soil amelioration by the use of fresh kelp is practised extensively in the Channel and Scilly Islands, and in parts of Ireland, particularly in connection with potato crops and especially early varieties, and root crops. (See G. H. Pethybridge, "Cultivation of Seaweed in Ireland," *J. Dept. Agric. and Tech. Instruction, Ireland*, April, 1915; also Seaweed, under Fertilizers, Miscellaneous.)

KIDNEY VETCH—Botanical Description—*Anthyllis Vulneraria*, lady's finger, sand clover; a perennial leguminous plant, extremely drought-resisting, and therefore most useful on the poor, dry, sandy and calcareous soils in areas of low rainfall. It possesses a deep, spreading root system, from which a rosette of foliage leaves arises in the first year; the leaves forming the rosette are simple and ovate, while in the second year the plant branches and the foliage develops a compound leaf with a large terminal lobe. The stems and foliage are slightly hairy, ending in a globular inflorescence, the flowers of which are a vivid egg-yellow colour. The large, thin, and inflated calyces are covered with downy hairs. The fruit is a single-seeded, flattened legume. The seeds are slightly kidney-shaped, and a little larger than those of red clover, the upper part of the seed being yellow or greenish-white, and the lower part a vivid green. If the seed is kept for a time the green colour slowly changes to a greenish-olive, and the yellow part changes in colour to a reddish-buff.

Soils and Climate—In Great Britain kidney vetch is cultivated in regions where the rainfall is low, and the soils dry and sandy or calcareous. It is, therefore, found most frequently in the eastern and southern counties of England, especially on poor, sandy soils overlying a calcareous subsoil.

Varieties and Seed Production—There are no distinct varieties, although the commercial seed stocks probably contain several distinct strains. When grown for seed, kidney vetch is sown under barley in spring, and unlike the clovers is left ungrazed or mown until the early part of August, when it is cut by machine and handled with care until stacked, for the seed shells out very readily. Although the husk is tough, the crop can be threshed in the same way as red clover, the yield being, approximately, a sack (20 stones) per acre. The residue after threshing may be fed to stock, although it is not eaten readily.

Cultivation—Kidney vetch occupies the place of clover in the four-course rotation, and is broadcasted or drilled under barley in the

KIDNEY VETCH (*Continued*)—

usual way. As with all small seeds on dry soils, better results are obtained by drilling; when required for sheep feed, it is usually sown alone and drilled at the rate of 16 to 20 lbs. per acre. Up to 30 lbs. of seed are sown when broadcasting. When the hay is required the rye-grasses are added, and a common mixture and seeding is 6 lbs. rye-grass and 14 lbs. kidney vetch per acre. It is often stated that kidney vetch will live in cultivation for several years, but although the plant is a perennial, it has little agricultural value as a permanent crop. When drilled alone and left for more than one year the resulting crops become progressively poorer, until nothing survives but a dense mass of weeds. Kidney vetch is often included, however, in small quantities in permanent seeds mixtures on poor, light land, with good results, the plant persisting for several years.

In the four-course rotation rye or oats is usually the following crop.

Utilization—Kidney vetch is associated with lands upon which sheep are essential. It is, therefore, utilized most frequently as a food for sheep, and may be either close-folded or ranged.

If it is ranged, or "run" as it is termed, feeding takes place early in the season when the plant is immature, but fed on it at that stage sheep are likely to "blow," and great care must be exercised in their management. When mature, the crop is a reasonably safe feed, and close folding, starting just as the plant flowers, is then the usual method of disposal.

In favourable seasons kidney vetch produces good crops of hay, and yields of up to 2 tons per acre are not uncommon. The hay when well "got" is valuable, and graziers speak highly of it. It is ready to cut about the first week in July, but, like trefoil hay, kidney vetch hay has a bitter taste, and horses, and sometimes other stock, may discard it at first.

Agricultural Importance—Like all legumes, kidney vetch enriches the land, and evidences of this in the succeeding crops are easily recognizable. It gives a reasonable prospect of a hay crop under conditions far too dry for the usual clover mixtures, and for that reason it is entitled to be regarded as one of the most valuable of the lesser cultivated crops. Because it is associated with soils that are always on the border of dereliction, its importance is minimized, and it is only when arable farming is really prosperous and these soils can be cultivated with profit, that kidney vetch has any national importance.

F. R.

LAVENDER (*Lavandula* spp.)—Lavender is cultivated commercially for two purposes. The first and more important aspect is the production of the oil of lavender of commerce. The second aspect is the production of lavender flowers, which meet with a ready disposal when sold either as bunched lavender, in a fresh condition, or as dried lavender.

The natural home of lavender is the mountainous region of the south-east of France, where the wild plant, *Lavandula Spica* L. and its natural hybrids, springs up spontaneously all over the rocky slopes.

LAVENDER (*Continued*)—

For many years these wild plants were the only source of the oil of lavender of commerce, but as the demand for a more superior production became established, the cultivation of lavender as a new industry came into being, and to-day the high-class oil of lavender produced from cultivated fields, and by modern methods of distillation, possesses its own marked and valuable characteristics which cause it to take first place in the market. In France the cultivation of lavender has made considerable headway during the last two decades, particularly in the vicinity of Grasse. Experiments have shown that the flowers of cultivated plants not only yield oil of higher quality, but a larger quantity than the wild plants, and, generally speaking, its ether content has a corresponding tendency.

In Great Britain lavender is grown on a smaller scale, and its development as a commercial crop has been somewhat impeded owing to the fact that the high duty on alcohol has tended to restrict the free expansion of the home perfumery industry.

The perfume known as "lavender water" is mainly a solution of oil of lavender and alcohol, and the particular alcohol employed is principally imported from the Continent. Against this must be set the established fact that the English oil of lavender cannot be equalled in quality by any of the Continental productions. This supremacy of quality results in its being preferred by high-class perfume manufacturers, and up to the present the cultivation of the lavender crop has, on the whole, been remunerative.

The English oil of lavender is produced by distillation of the flowers of the English or Mitcham lavender, *Lavandula vera*, and this is the variety always cultivated. Mitcham lavender succeeds best in deep, calcareous loams, although the lighter loams of other formations will suit the crop provided adequate applications of lime or chalk are given. As in the case of other essential oil plants, lavender requires a liberal amount of sunshine, whilst some shelter from strong winds is also desirable.

General Cultivation—In recent years the disease known as Shab (*Phoma lavandulæ*) has proved very destructive, but research work carried out at Cambridge has shown that a substantial amount of control may be obtained over this disease provided certain methods of cultivation are adopted. The old method of propagation by division was largely instrumental in spreading the Shab disease.

Lavender bushes for planting up a new field should be raised from cuttings taken off with a heel, from healthy plants in September, and rooted in sand, or sandy soil, in cold frames. The cuttings should be near the glass, and as soon as roots are formed the tops of the plants should be pinched out. The following spring all rooted cuttings should be planted out in a nursery bed to be grown on, and they may be planted out in their permanent quarters as two-year-old plants—that is, in the autumn of the second year following the taking of the cuttings. Spring planting may also be done. Frequent pinching should be practised while the plants are in their nursery quarters to

LAVENDER (*Continued*)—

promote compact, bushy growth. It is very undesirable to plant in the winter, as the plants, being of a temperate to sub-tropical genus, are particularly sensitive to frost damage in the region of the roots. Winter planting, and too drastic cultivation with horse-hoes or motor machinery, account very often for the wilting and dying off of sections of the plants, although the Shab disease referred to above will induce somewhat similar symptoms. The lavender plants should be planted out 3 ft. square, or 3 ft. apart with 4 ft. between the rows, the latter distance allowing more room for horse or motor cultivation. Although it tends to increase the labour costs, hand-cultivation is to be preferred, unless the greatest care is exercised with the horse or motor implements.

Where the production of oil of lavender is the object, the crop is cut when the flowers are fully out, usually towards the end of August. About 6 ins. of the stalk is usually put into the still with the flower heads, but in gathering the crop the stalks should be cut at full length, cutting well into the bush at their base. This method of cutting also prunes the bushes effectively, and will maintain a close, compact habit and engender a wealth of fresh growth for the next crop. No further pruning is necessary, and on no account should the bushes be touched again in the spring.

Unless arrangements can be made for the use of a neighbouring still, the grower must provide a still on his own premises to deal with the crop.

The modern lavender oil still differs widely from the open fire stills used in the old days for dealing with the wild lavender crop. These modern stills with the latest technical improvements can deal with the charge so rapidly as to avoid hydrolysis of the ether, and as distillation is carried out with the same steam pressure, and other conditions are constant, the uniformity of the product is maintained. The yield of oil will fluctuate from year to year, being affected by weather conditions, age of bushes, and other factors. A fair yield is from 10 to 16 ozs. from 1 cwt. of flowers, and from 15 to 20 lbs. of oil is regarded as a fair yield per acre.

It has been pointed out that English oil of lavender commands a higher selling value than imported oils. Merchants who trade in essential oils are usually prepared to purchase the grower's crop of oil, but should he elect to store the oil against sale it should be kept in blue Winchesters holding about 80 ozs., and these should be placed in a dark, cool store-room. From three to five years' storage is necessary before the oil is matured sufficiently for use in the perfumery and other trades which use it.

Fresh lavender flowers are marketed in bunches containing a hundred heads, or in smaller bunches if for special sale to retailers. The flowers should not be so fully out as when used for distilling. Dried lavender is obtained by spreading the lavender thinly on shelves in a dry shed as it is cut, and when dry removing the flowers from the stalks by hand or with the aid of sieves.

In commercial practice lavender bushes are seldom retained after

LAVENDER (*Continued*)—
the fifth year of cropping; they should then be grubbed and burned. To maintain a constant acreage from year to year a certain amount of grubbing and replanting must be undertaken each year, in addition to the appropriate amount of propagation to maintain the supply of bushes.

LEACHING—The washing out of soluble material from soils. When rocks weather and gradually break up, their more soluble constituents are carried away by the rain water which washes them. The total amount carried away may amount to as much as 98 per cent. in the case of some calcareous rocks. The composition of the sea and of river waters shows that one of the principal things so removed is sodium chloride together with other material which, if allowed to remain, would eventually produce an alkaline soil. In districts where such soils do occur it appears to be due to the arid climates; a certain amount of rain does fall, but this, while sufficient to moisten the soil, is not enough to carry to the main streams all those compounds which occur only in minimal quantities in fertile soils. Hence, proper leaching in the first place is an essential for the formation of a really fertile soil for most crops; it is, in short, this leaching out which makes the difference between soil and merely disintegrated rock. Similar accumulation of undesirable products is observed in marsh soils where the water remains more or less stagnant.

Clearly, excessive rain may succeed in leaching much useful material out of the soil, and Nicholson and Pantin (*J. Agric. Sci.*, xix., 297, 1929) have recently confirmed some earlier work done at Rothamsted showing that autumn dressings of nitrogenous fertilizers may be leached out of the soil to the extent of 50 per cent. or more, at any time up to April of the following year. The actual fertilizers they used in their tests were ammonium sulphate, rape dust, and cyanamide. It is obvious from theoretical considerations, as well as being established by observation, that leaching may also be a cause of loss of lime, whether this is present naturally or has been applied. (See Lime and Liming, also Lysimeters.)

LEAD (symbol Pb; atomic weight 207·2; atomic number 82). A metallic element of high specific gravity. Apparently the ultimate stable form to which uranium and radium tend. Of agricultural importance as a component of various insecticides (*q.v.*), also from its use in pipes for conveying gas, water, etc., and as a protective covering for light electric cables buried in the soil.

LEAF STRIPE—See Diseases of Cereals, under Wheat.

LEATHER WASTE—See Fertilizers, Miscellaneous.

LEGUMES, BREEDING OF HERBAGE—The great advance in our knowledge of the fundamental principles of inheritance in plants that has been made during recent years has paved the way for the production of improved strains on scientific lines. Very considerable progress

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

has been made in certain directions, but for various reasons plant breeders have, until quite recently, confined their attention mainly to the study and improvement of self-fertilized crops. In spite of the great importance of herbage legumes, both as fodder crops and as soil improvers, the breeding of these plants has been sadly neglected; it is only within the last few years that sustained efforts have been made to improve these crops. Although a considerable amount of work is now being carried out both on the Continent and in North America on some of the crops, the amount of information available on methods and technique of breeding and modes of inheritance, even for lucerne and red clover, the two crops that have been most extensively studied, is still very scanty.

In all breeding investigations the actual material employed as parent stocks will depend on the aims which the breeders have in mind. Having defined these aims, the next step is to search for types possessing as many of the desired characteristics as possible. Before deciding on the material to be used, it is generally necessary to carry out a number of field tests with a large number of varieties and forms. The actual method of breeding must of necessity depend on the mode of reproduction and the floral mechanism of the plants involved, an accurate knowledge of which is essential before an appropriate technique can be devised. Most of the herbage legumes which will be considered here are naturally cross-fertilized; many are in fact practically self-sterile. Although the underlying principles of breeding are the same for both self- and cross-fertilized crops, the methods and technique which have been applied with such signal success to the breeding of cereals and other self-fertile crops are not applicable to cross-fertilized plants such as red and white clovers, owing, in the first place, to the obvious impossibility in the case of self-sterile crops of producing homozygous lines by self-fertilization, and in the second place, to the difficulties associated with loss of vigour due to inbreeding. The breeding of herbage legumes is rendered still more complicated by the fact that many of the crops are naturally pollinated by bees.

As the same general methods are applicable to all the crops cross-pollinated by bees, in the interest of space the methods and technique of breeding of only two such crops, red clover and lucerne, will be considered here in detail.

Red Clover (*Trifolium pratense* L.)—This clover, which is one of the most valuable of the leguminous crops, is essentially a hay plant, and is pre-eminently suitable for short leys, either alone or in mixtures. It is also capable of producing excellent pasturage, but being a relatively short-lived plant, it is less suitable for this purpose than white clover.

There are a very large number of different varieties and nationalities of red clover, all of which, however, fall naturally, according to certain important characteristics, into three major groups, namely, early flowering, late flowering, and wild red clovers. Under British conditions,

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

the early clovers behave in the main as biennials, and are, therefore, only suitable for one year leys; late clovers, on the other hand, are chiefly semi-perennials, being capable of lasting from two to four years. The wild reds form a highly variable group, but are generally considerably less productive under ordinary conditions than the cultivated varieties. (See Red Clover.)

In many respects red clover is a happy hunting ground for the plant breeder. It is extremely variable, and on that account its potentialities for improvement are very great. In all varieties types may be selected which vary widely in a great many characters, such as productiveness, persistency, winter hardiness, rate of growth, time of flowering, leafiness, resistance to various diseases such as Anthracnose (*Glœosporium caulivorum*), Leaf Spot (*Pseudopeziza trifolii*), and Clover Sickness (*Sclerotinia trifoliorum*).

During recent years the problem of self-fertility in red clover has received a considerable amount of attention from several workers. Though there is general agreement that the crop is mainly cross-fertile, it appears from the results of these studies that its degree of self-fertility varies within narrow limits under different conditions. Most workers conclude from their investigations that it is either completely self-sterile or only slightly self-fertile; some investigators, however, have found that it contains a few moderately self-fertile plants. At Aberystwyth, where this problem has been studied for nine consecutive seasons, it has been found that the amount of self-fertilization that occurs in red clover is practically negligible, though a few plants have been isolated which are capable of producing a fair amount of seeds when artificially self-pollinated.

Until quite recently the method used in breeding red clover was a restricted form of mass selection. Sometimes, when breeding for disease resistance or winter hardiness, there is no attempt at deliberate selection, for the elimination of the undesirable plants is left entirely to external influences. The seed from the surviving plants is saved and sown again under similar conditions, the process being repeated several times. In most cases, however, the plants to be selected are spaced so that their characteristics can be determined. The undesirable plants are removed before they bloom, and seed is harvested from the selected plants. By repeating this process for several generations it is claimed that it is possible to obtain a fair degree of uniformity in the desired characters.

Despite its manifest limitations, this scheme has proved to be quite effective in bringing about an appreciable amount of improvement in certain directions, as is shown by the fact that several improved strains of red clover, such as disease-resistant clover immune to the American form of Anthracnose bred by Bain and Essary (" Selection of Disease-resistant Clover," *Tenn. Agric. Expt. Sta., Bull.* 75, 1906), and two winter hardy strains—Altaswede, bred by Cutler and Buckley (" Altaswede Red Clover," *Univ. of Alberta, Bull.* 4, 1923), and Manhardy, bred by Southworth—have been produced in this manner. It is still the method most generally employed both on the Continent

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

and in America. Its chief merit lies in its simplicity, but owing to certain inherent defects the amount of improvement which can be effected by this method must of necessity be very restricted. In the first place, since the selection is based entirely on the phenotypical characteristics and not on the genotypical constitution of the plants, it is practically impossible by a system of mass selection to breed strains pure even for relatively few characters. Again, mass selection as usually practised does not permit effective control over pollination. As in all other cross-fertile legumes, fertilization in red clover is effected through the instrumentality of bees, and unless the selected plants are isolated at a considerable distance from other red clover, they will be promiscuously crossed by bees with any red clover that may be within reach. Various methods have been adopted by different workers to circumvent this difficulty. The method used by Lindhard ("Om rødkløverens bestøvning og de humlebiarter, som herved er virksamme," *Tidsskr. Planteavl*, 18, 1911) was an ingenious one. The selected plants were protected from promiscuous pollination by covering them with bee-proof cages. When the plants were in bloom, humble-bees, which presumably had been cleaned of foreign red clover pollen by placing them in a cage with *Lotus corniculatus* in flower, were introduced into the cage. The method employed by Frandsen ("Undersøgelser over Bestøvnings-og Befrugtningsforhold hos nogle Græs-og Bælgplantearter paa Forsøgsstationen ved Tystofte," *Tidsskr. Planteavl*, 23, 1916), Schlecht ("Untersuchungen über die Befruchtungsverhältnisse bei Rotklee (*Trifolium pratense*)," *Z. Pflanzenz.*, viii., 1921), and some of the other Continental breeders is very similar, except that as a rule no special precautions are taken to clean the bees before they are introduced into the cages, apart from using bees captured on flowers other than those of red clover. Dreger ("Gesammelte Erfahrungen eines Pflanzenzüchters," *Z. Pflanzenz.*, ix., 1923) reports having used another method of controlling pollination with a considerable degree of success, whereby the breeding plots were surrounded by borders—3 metres wide—of *Vicia villosa*. It is claimed that the bees visited the flowers of the vetch, and in doing so were freed of red clover pollen before they visited the clovers. This method, as the writer has shown elsewhere (Williams, R. D., "Studies concerning the Pollination, Fertilisation, and Breeding of Red Clover," *Welsh Plant Breeding Sta. Bull.*, Ser. H., 4, 1925), is, however, not effective in preventing promiscuous cross-pollination under the conditions prevailing at Aberystwyth.

As a direct outcome of their investigations on self-fertility, Fergus ("Self-fertility in Red Clover" [a report of progress on an attempt to secure self-fertile lines in this crop], *Kentucky Agric. Expt. Sta.*, *Cir.* 29, 1922), working in California, and Kirk ("Artificial Self-Pollination of Red Clover," *Sci. Agric.*, v., 1925) in Canada have tentatively suggested another method of breeding red clover. Their results show that self-fertility in red clover is an inherent character, and that consequently it is possible to isolate fairly highly self-fertile lines. The crop, according to these two workers, contains a small proportion

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

of plants which are sufficiently self-fertile to justify an attempt to produce homozygous lines by self-fertilization. This may be the case under certain conditions, but the results obtained at Aberystwyth have shown quite definitely that there this method has very little prospect of success on account of the extreme self-sterility of red clover in this country.

During the last nine years a great deal of work on the methods and technique of breeding certain herbage legumes, particularly red clover, white clover, and lucerne, has been conducted at Aberystwyth. Various systems have been tried from time to time, but the method that has been found to hold the greatest prospect of success, and the only one now used, is inbreeding. Every year several thousands of plants of the best varieties are planted out singly in the field for selection of parents. These plants are kept under close observation for a certain number of years, depending on the variety and aims of breeding. For instance, when the object is to breed strains of increased permanence, the plants are generally left in the field for four years before the parent plants are finally selected. All hybridization is now done under glass, as experience has shown that in most seasons the months of July and August are too wet to allow this work to be done in the field.

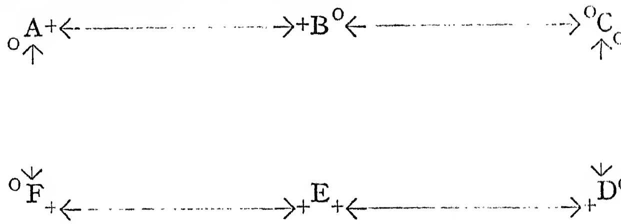
Most of the actual crossing work is now done on cuttings taken from the selected plants. During the initial breeding stages the plants are always crossed in pairs. Two methods of crossing are employed. The crosses intended for genetical study are generally done by hand. Since most of the plants are completely self-sterile emasculation is not necessary, but in every case a few florets on each plant are artificially selfed as a precautionary measure. Most of the crosses made with the object of producing improved strains are effected by clean humble-bees under controlled conditions in a specially constructed bee pollination glass-house, which is partitioned off into a large number of bee-proof compartments. The selected sister plants of each of the succeeding generations are crossed in a similar manner. After about three or four generations of inbreeding, some of the lines, though they may not be homozygous in respect of many characters, are generally pure for most of the desired properties.

In common with many other cross-fertilized crops, red clover shows a very marked decrease in vigour as a result of inbreeding. The loss of vigour is generally very pronounced in the second generation, but becomes less evident in each succeeding generation.

The effect of inbreeding is more marked in some lines than in others. Some families show a reduction, as determined by weight of produce, of 50 to 60 per cent. in the second generation, while others show a loss of only 10 to 20 per cent.

It is often stated that inbreeding in red clover is accompanied by a reduction in cross-fertility. This, however, is only a half-truth. When sister plants obtained by inbreeding are intercrossed, some are reciprocally fully cross-fertile, while others are reciprocally cross-sterile. This phenomenon may be illustrated diagrammatically thus:

LEGUMES, BREEDING OF HERBAGE (*Continued*)—



The letters represent sister plants reciprocally crossed—A $\times$ B, B $\times$ C, etc.—while + denotes cross-fertility and o complete cross-sterility. The numerous sister crosses which have been made in different generations from F_1 to F_6 have all, with a very few doubtful exceptions, behaved in the manner illustrated, and on the average the seed setting from the compatible sister plants was as high as that obtained when unrelated plants were intercrossed. A certain amount of evidence has been obtained which seems to indicate that cross-sterility in red clover is determined by a series of multiple allelomorphs, as has been found to be the case in *Nicotiana Sanderæ*, plums, cherries, and certain other species.

It is clear, therefore, that the inbred lines as such, though they may be breeding true in respect to many important properties, are of little practical value owing to their lack of vigour. Before they can be put to practical use, the vigour lost through inbreeding has to be recovered. This is best effected by a process which may be termed "strain building," in which a number of plants from three or more of the best inbred strains showing similar properties are grouped together and allowed to intercross under strictly controlled pollination conditions, under glass by means of clean bees. By this method enough seed is obtained (in some cases over 50,000 seeds have been secured from about forty plants) to carry out the next stage in clover breeding—namely, the production of sufficient seed for conducting strain tests. In this connection it is important to bear in mind that red clover is naturally cross-fertilized by bees. In order to maintain the purity of the new strains it is essential that a moderately large area, not less than one-tenth of an acre, of each strain should be sown or planted, and that each strain should be isolated at some considerable distance from any other red clover.

According to Wexelsen ("Chromosome Numbers and Morphology in *Trifolium*," *Calif. Univ. Pub. Agric. Sci.*, 2, 1928), Karpechenko ("Karyologische Studien über die Gattung *Trifolium* L.," *Bull. Appl. Bot. Plant. Breed.*, Leningrad, 14, 1925), and Bleier ("Chromosomenstudien bei der Gattung Trifolium," *Jahrb. wiss. Bot.*, 64, 1925), the number of chromosomes is $2n=14$. The study of inheritance in red clover has been much neglected, and though a certain number of investigations have been conducted on the genetics of flower, and seed colours, and a few other characters, most of these studies are open to criticism, as they were carried out on the progenies of open pollinated plants.

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

De Vries ("Die Mutationstheorie," vol. ii., Leipzig, 1903) found a single factor, and Kajanus ("Über die Farben der Blüten und Samen von *Trifolium pratense*," *Fühlings landw. Ztg.*, 61, 1912) a two-factor difference between red and white flower colour. The results obtained by Raum ("Ein weiterer Versuch über die Vererbung der Samenfarbe bei Rotklee," *Z. Pflanzen.*, vii., 1920) and Gmelin ("Proefnemingen met de roode-klaver. Tweede reeks van onderzoekingen met betrekking tot de roodeklaververedeling," *Cultura* 28, 1916), however, seem to indicate that flower colour is more complex.

As regards seed colour, some of the purple × yellow and yellow × white crosses made by Witte ("Några iakttagelser öfver fröfärgen hos rödklöfvern och dess ärftlighetsförhållanden," *Sverig. Utsädesfören. Tidskr.*, xxxi., 1921) showed monohybrid segregation with purple dominant to yellow and yellow dominant to white, but contradictory results were given by some of his other crosses.

Polyphylly has been studied by several workers. Some investigators have reported that though this character is greatly affected by external conditions it is probably due to a single factor difference. Columbus Jones ("Studies concerning the Occurrence and Development of Multifoliate Leaves in Red Clover," 1930 [unpublished]), however, concluded as a result of exhaustive studies conducted under controlled pollination conditions that at least two factors are concerned.

Alsike (*Trifolium hybridum* L.)—Owing to its short growing period alsike is more suitable for the production of hay than for pasturing. It occupies a position somewhat similar to late red clovers in the general scheme of farm economy. Though it is generally neither so persistent nor so productive as the latter on most types of soil, it is better adapted to damp clay and peaty soils than red clover. It generally takes the place of red clover on clover-sick land, as it is more resistant to *Sclerotinia* than the latter. Alsike does not seem to be nearly as variable as red clover, and for that reason does not offer the same scope for improvement. The flowers are almost exclusively pollinated by honey bees. Witte ("Om självsteriliteten hos rödklöfvern," *Sverig. Utsädesfören. Tidskr.*, xix., 1909) and Jørgensen ("Om Bestøvningsog Befrugtningsforhold hos nogle Græsmarksbælgplanter med Henblik paa deres Forædling," *K. Vet. Højsk. Aarskr.*, 1921) found that the plants are self-sterile to a very marked degree. On this account the methods employed in the breeding of red clover are equally applicable to the breeding of alsike. According to Bleier (*loc. cit.*, 1925), Karpechenko (*loc. cit.*, 1925), and Wexelsen (*loc. cit.*, 1928), the diploid number of chromosomes in this species is sixteen.

White Clover (*Trifolium repens* L.)—White clover, of which there are several forms, is undoubtedly one of the most valuable of our pasture plants. The chief forms usually grown in this country are ordinary or Dutch, New Zealand (both ordinary and wild), and indigenous wild. The Dutch white is relatively short-lived, and is, there-

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

fore, suitable for one or two year leys; wild white, on the other hand, is a very persistent form, and under proper treatment will generally hold the ground for a considerable time, and is consequently invaluable for long leys and permanent pastures. As regards their general characteristics the New Zealand whites are intermediate between these two forms; they are less persistent than the indigenous wilds, but are generally more productive during the first two or three years, and on that account they are particularly suitable for one to three year leys. (See Wild White Clover.)

White clover is extremely variable; numerous types showing wide differences in productiveness, density of growth, rate of spreading, earliness, leafiness, permanence, and many other important agricultural properties may be found in almost all the forms. It is possible, for instance, to select from any sample of wild white clover slow-growing plants which are only capable of spreading from 1 to 2 ft. a year, on the one hand, and, on the other, very rapid-growing plants with an annual spread of about 5 ft. It is evident, therefore, that white clover offers ample room for improvement. In spite of its great potentialities for improvement, owing to the manifold difficulties associated with its mode of reproduction, until quite recently practically no breeding work has been done on this crop.

According to the results of the pollination studies conducted by various investigators, white clover is almost completely self-sterile. For instance, Ware ("Experiments and Observations on Forms and Strains of *Trifolium repens* L.," *J. Agric. Sci.*, xv., 1925) obtained only six seeds from about 500 artificially pollinated flowers. The results obtained by the writer also indicate that although white clover, on the whole, is highly self-sterile, it nevertheless contains appreciably more plants capable of producing seeds on being artificially self-pollinated than red clover.

White clover, therefore, appears to offer greater opportunities for improvement by isolation of self-fertile lines than red clover. Though it is possible that considerable improvement may be achieved by mass selection, the method that holds out the greatest prospect of success is the process of inbreeding followed by strain building similar to that described for red clover. The plants may be cross-pollinated by hand or by means of clean bees, using honey bees or *Bombus terrestris* workers in preference to *B. hortorum* or *B. agrorum*, which are generally used for pollinating red clover.

According to Karpechenko (*loc. cit.*, 1925) and Wexelsen (*loc. cit.*, 1928), the diploid number of chromosomes in white clover is thirty-two, but the number reported by Bleier (*loc. cit.*, 1925) is only twenty-eight.

The study of the genetics of white clover has been even more neglected than that of red clover. The only investigations so far reported are those conducted by Erith ("Some Hybrids of Varieties of White Clover [*Trifolium repens* L.]," *J. Genetics*, 19, 1928) on flower colour, reddish purple pigment on the leaves and cyanophoric properties.

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

Crimson Clover (*Trifolium incarnatum* L.)—This annual clover is confined chiefly to the south of England, where it is generally sown on the stubbles in the autumn to be fed off in the following May or June. There are three varieties in commerce—early, late, and white-flowered.

Pollination is effected almost entirely through the agency of bees. A few plants have, however, been found which are capable to a very slight degree of spontaneous self-fertilization, while most of the plants so far studied have been found to set seed quite freely on being artificially self-pollinated.

Despite the fact that crimson clover appears to be moderately rich in elementary forms which could be readily isolated by artificial self-fertilization, as far as the writer is aware no attempt has yet been made to produce improved strains on these lines.

Subterranean Clover (*Trifolium subterraneum* L.)—This is an annual plant which is able to perpetuate itself for a number of years by virtue of its self-seeding habit. It is extensively grown in many parts of Australia, where it supplies invaluable pasturage during the dry seasons. As the commercial seed from Australia is only a recent introduction, it is as yet very little sown in this country. Under certain conditions it produces a considerable amount of valuable winter and early spring grazing, for which purpose it is only excelled by Italian rye-grass.

The plants are completely self-fertile, the flower being cleistogamic. They flower normally during May or early June, and soon after fertilization has taken place the pods are buried in the ground—the seeds germinating during July, August, and September.

It is only necessary to sow the seeds of individual plants separately on a plant-row basis to see that the cultivated variety contains a large number of forms differing in many important properties, such as productiveness, winter hardiness, earliness, and seed setting; and on account of its mode of reproduction it is a comparatively easy matter to isolate types superior in certain qualities to the existing cultivated form.

Yellow Suckling Clover (*Trifolium dubium* Sibth.)—This is an annual clover which can be found growing indigenously on many types of soil. It perpetuates itself by self-seeding. As it is not very productive, it is seldom included in mixtures, except on rather poor, light land, where it often produces excellent grazing for sheep.

So far no attempt has been made to improve this species by breeding, though there appears to be no doubt that considerable improvement could be effected with very little expenditure of time and labour, as it seems to be rich in distinctive forms and is fully self-fertile.

Lucerne (*Medicago sativa* L.)—Lucerne is more exacting in regard to soil and climatic conditions than most crops. Under dry climatic conditions it can generally be grown successfully on most types of soil, but under humid conditions it seldom produces satisfactory

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

crops except on deep, fairly fertile, well-drained soils rich in lime. For this reason it is rarely grown in the west and north of Britain, its culture being confined chiefly to the south-east of England. Under conditions where it can grow successfully, it is an exceedingly valuable fodder crop, owing to its high yielding capacity, high nutritive value, ability to resist drought, and permanence.

Lucerne consists of several varieties and regional strains which differ considerably in many important agronomical characteristics, but which, however, fall naturally into two main classes, namely, (1) the blue flowered or common lucerne, such as Provence, Peruvian, Turkestan, and Arabian, all of which are varieties of *M. sativa*; and (2) variegated lucerne, such as Grimm, Canadian variegated and sand lucerne, which have apparently originated as a result of natural crossing between ordinary blue-flowered lucerne (*M. sativa*) and the hardy, yellow-flowered, sickle lucerne (*M. falcata*). In this country the variety generally grown where the conditions are favourable, as in the south-east, is Provence, preferably English grown, but under more adverse conditions Grimm and Canadian variegated lucerne have been found to give the best results.

Lucerne, as numerous workers have shown, is exceedingly variable; every variety is, in fact, a collection of diverse individuals differing very widely in their morphological, physiological, and agricultural characteristics. The extreme variability of the individual plants constituting different varieties has been amply demonstrated in regard to resistance to drought and frost, general growth habits, stem-, leaf-, seed-, flower-, and other characters. Three main types of root systems have been distinguished, namely: (*a*) root system without underground stems; (*b*) branched tap roots with well-defined underground stems; and (*c*) branched tap roots with buds and aerial roots. Individuals with roots of types (*b*) and (*c*) were found to be more vigorous and productive and more winter-hardy than those with single tap roots. Hardiness appears to be closely associated with much-branched root system and spreading crowns, and the permanence of Grimm is probably in some measure due to the rhizomatous nature of the roots of many of the plants.

The problems relative to the fertilization of lucerne have been subjected to a great deal of investigation in recent years. It is now generally agreed that insects, more particularly humble-bees, play an all-important rôle in effecting fertilization in lucerne, but it is not yet known to what extent seed setting in the field is due to self-pollination, though the weight of evidence available seems to favour the view that seed setting under natural conditions is mainly the result of cross-pollination. The amount of automatic self-fertilization varies not only in different plants, but also from season to season and in different localities. There is a close agreement, in the results obtained by most workers, that lucerne is on the whole fairly self-fertile when artificially self-pollinated, though the individual plants show wide differences in this respect. Piper *et al.* ("Alfalfa Seed Production: Pollination Studies," *U.S. Dept. Agric. Bur. Plant Ind.*,

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

Bull. 75, 1914) report that 30·7 per cent. of the flowers which they artificially tripped produced seeds. Similar results have been obtained by other investigators. Frandsen (*loc. cit.*, 1916) obtained in one year 36·7 per cent., in the next year 35·1 per cent. successes; Jørgensen (*loc. cit.*, 1921) 44·1 per cent., and Southworth ("Influences which tend to affect Seed Production in Alfalfa and an Attempt to raise a High Seed-Producing Strain by Hybridisation," *Sci. Agric.*, ix., 1928) 46·5 per cent. from artificial self-pollination, while Helmbold ("Untersuchungen über die Befruchtungsverhältnisse, über die Bedingungen und über die Vererbung der Samenerzeugung bei Luzerne [*Medicago sativa* und Bastardluzerne]," *Z. Pflanzenz.*, xiv., 1929) obtained from 70 to 75 per cent. as much seed from artificial self-pollination as from artificial cross-pollination.

In breeding lucerne there are two lines of approach which offer considerable promise of success, namely, (1) the production of homozygous lines by self-fertilization of plants showing desirable characteristics selected from existing varieties; and (2) the production of new strains by hybridization, whereby two plants are intercrossed with the view of combining the good qualities of both parents in one line. As lucerne is to a large extent self-fertile, it is necessary to emasculate the flowers of the mother plants before they are cross-pollinated. Depollination is usually effected by the water jet method, though the suction method has been very successfully employed by Kirk ("Abnormal Seed Development in Sweet Clover Species Crosses —A New Technique for Emasculating Sweet Clover Flowers," *Sci. Agric.*, x., 1930) for the same purpose. According to some investigators the flowers should be emasculated before they are in the straight bud stage, because the anthers dehisce during this stage; Southworth ("Alfalfa Hybridisation," *Sci. Agric.*, ii., 1922), however, reports that his attempts at emasculating the flowers during the bud stage were not successful, the best results being obtained when newly opened flowers were used. In self-pollinating lucerne the method usually adopted is to trip the flowers by running the racemes through the hand.

Under favourable conditions pollination is done in the field; the plants are usually protected from insect visitors by means of tiffany or wire gauze cages. Where the conditions are not so favourable to seed setting, the work is usually carried out under glass, using cuttings of the selected plants. In lucerne, as in most other naturally cross-fertilized plants, there is usually a very marked loss of vigour due to inbreeding. As a result of extensive investigations Kirk ("Self-Fertilisation in Relation to Forage Crop Improvement," *Sci. Agric.*, viii., 1927) found that there was on the average a pronounced and progressive reduction in seed yield as well as in vigour of growth for each generation of selfing. A few lines, however, retained their vigour even after two and three generations of inbreeding.

Judging from the progress already made in the production of superior strains of lucerne, there is no doubt that considerable improvement can be effected in the direction of greater yield, winter hardiness,

LEGUMES, BREEDING OF HERBAGE (*Continued*)—
permanence and disease resistance by systematic selection and inbreeding. Equally promising results have been obtained from *M. sativa* × *M. falcata* crosses. Certain characters are, however, not so amenable to improvement as others. Except under very favourable conditions lucerne is a very erratic seed producer, and in humid climates it rarely yields a satisfactory seed crop. Although a great deal of time has been devoted to the problem, very little progress has yet been made in improving the seed-setting propensities of the crop. An attempt has been made by Southworth (*loc. cit.*, 1928) to overcome this difficulty by crossing lucerne with *M. lupulina*, which normally sets seed very freely. Southworth reports that there is reason to hope that a strain possessing a high degree of fertility will be isolated from this cross.

According to Bleier ("De beteekenis van de cytologie voor de plantenveredling," *Landbouwk. Tijdschr.*, 41, 1929) the diploid number of chromosomes in lucerne is thirty-two. Our knowledge concerning the genetics of lucerne is very limited. In crosses between blue-flowered *M. sativa* and yellow-flowered *M. falcata*, the F_1 generation is intermediate in regard to flower colour, form of the pods, and other characters, while the F_2 generation gives a very complicated segregation.

Bird's-foot Trefoil (*Lotus corniculatus* L. and *L. major*, Sm.)—Both the lesser and greater bird's-foot trefoils are perennial plants indigenous to Britain, the former being generally found on the lighter types of soils and the latter on heavy, damp, and marshy soils.

Although both species, and particularly *L. corniculatus*, are very palatable to stock and have high nutritive values, they are comparatively little sown in this country, very largely on account of their inability to withstand heavy grazing, especially during the seeding year and early in the spring. At Aberystwyth a certain amount of evidence has been obtained which seems to indicate that certain forms of *Lotus major* are particularly adapted to soils of low fertility in districts of high elevation. There is every reason to believe that greatly improved strains with a much higher degree of permanency can be produced from the existing material by careful selection and breeding. Both species are exceedingly rich in types varying widely in respect to yielding capacity, leafiness, persistency, and other important characteristics. In the case of greater bird's-foot trefoil the individual plants exhibit extreme variability in regard to the production of underground stems, a property which appears to be fairly closely connected with the degree of permanency of the plants. In *L. corniculatus*, the ability to spread by means of rhizomes, though fairly well developed in a few plants, is far less pronounced than in *L. major*.

Both species are highly cross-fertile, the interpollination being effected by bees. Individual plants show wide variation in degree of self-fertility. Witte (*loc. cit.*, 1909) found that *L. corniculatus* was competely self-sterile when the flowers were protected from insects;

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

and Jørgensen (*loc. cit.*, 1921) also obtained no seeds from *L. major* when similarly protected, but as only a few flowers were tested, the results obtained by these two workers are not conclusive. As a result of much more extensive studies on *L. corniculatus*, Frandsen (*loc. cit.*, 1916) concluded that a narrow-leaved form—var. *tenuifolium*—was moderately self-fertile, especially when artificially self-pollinated, while a broad-leaved form was highly self-sterile, only an occasional seed being produced. At Aberystwyth it was found that while most of the plants of both species were almost completely self-sterile, a small proportion of the plants studied produced a fair number of seeds on being artificially selfed. In view of this fact, it is tentatively suggested that it may be possible by continuous inbreeding to isolate highly self-fertile plants of these species, and should that prove to be the case it would facilitate breeding work very considerably. But the method which is likely to be most successful is that adopted in breeding red and white clovers, which has been described previously.

R. D. W.

DISEASES OF PASTURE AND FORAGE CROPS—In Britain more than forty species of fungi have been recorded on grasses and clovers of economic value (" Preliminary Observations with Herbage Plants," *Welsh Plant Breeding Stat. Bull.*, Series H, No. 1, 1919-1921). Some cause diseases of considerable practical importance, while others rarely or never give rise to serious epidemics. An attempt has been made to estimate the economic importance of the species under review, and the discussion is confined to those which are known most frequently to reduce the yield and value of pasture and forage crops.

Rot of leguminous plants, a disease caused by *Sclerotinia trifoliorum* Erikss, is undoubtedly in certain districts a limiting factor in the cultivation of clover. The fact that all our common species of Trifolium, as well as trefoil, lucerne, and sainfoin, are in some degree susceptible to this fungus explains the great difficulty of eradicating this type of clover sickness. " Clover sickness " is sometimes used to describe the Eelworm disease of clover.

The attack occurs chiefly in the autumn, when infected plants show brown spots followed by withered foliage. Small, irregularly shaped, black sclerotia are formed during the winter months on dead or dying plants. They can remain dormant in the soil for several years. In October or November those which are not buried too deeply give rise to stalked apothecia. These discharge ascospores which infect the leaves and stems of healthy clover plants. Rot spreads most rapidly when the winter is mild and moist, but not too wet. Under suitable conditions the mycelium is seen as a white, silky covering on infected foliage. A long period of cold weather in the early autumn will check the disease, but a rise of temperature may be followed by a second outbreak. Any treatment, manurial or otherwise, which tends to encourage a luxuriant growth of clover late in the season increases the danger of damage by Rot. It is suggested that the danger can be minimized by close grazing in September (A. Amos,

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

"The Difficulties of growing Red Clover: Clover Sickness and Other Causes of Failure," *J.R.A.S.E.*, lxxix., 68-88), but such treatment may possibly have an adverse effect on subsequent growth. It is generally held that the causal organism of Clover Rot is not one which shows the phenomenon of biological specialization to any marked degree, but recent work in Sweden gave results which indicated that strains exist differing slightly in their reaction to specific hosts (G. Nilsson-Leissner and Nils Sylven (1929), "Studies in *Sclerotinia trifoliorum*" (trans. title), *Sveriges Utsädesforenings Tidskrift*, xxxix., 130.) It has been demonstrated also that some types of red clover are less susceptible than others, and breeding resistant varieties undoubtedly offers the greatest hope of eliminating this disease from leguminous crops.

The recent discovery that samples of white clover from New Zealand sometimes contain seeds which carry in their coats mycelium of *Sclerotinia trifoliorum* emphasizes the possible danger of introducing the fungus to clean land by means of infected seed (N. L. Alcock, "Seed of *Trifolium repens* L. carrying a Fungus resembling *Sclerotinia trifoliorum*, Clover Stem Rot"; *Extrait de Comptes rendus de l'Association Internationale d'Essais de Semences*, No. 6, 1928. Copenhagen V.). (See in this connection Seed, Transmission of Plant Diseases by.)

A disease which perhaps ranks second in importance to rot is Scorch of red clover caused by *Kabatiella caulivora* (Kirchn.) Karak. At flowering time, long black lesions are conspicuous on the stems, while petioles, leaflets, and flower heads hang down limply and finally wither. A second attack often occurs in the late growth, and young seedlings may also suffer serious damage. The disease is spread by sickle-shaped conidia which appear in minute pustules on the discoloured plant tissues. There is evidence to show that spores present on seed coats retain their viability for some months and can infect the cotyledons when the seed germinates. Soil containing conidia produced the disease when brought into contact with leaves of red clover. Mycelium remains viable in the leaf stalk during the winter and serves as a certain link between one season and the next (K. Sampson, "Investigations on Anthracnose of Red Clover due to *Glœosporium caulivorum* Kirchn.," *Welsh Plant Breeding Stat. Bull.*, Series H, No. 1, pp. 83-87, 1922. "Comparative Studies of *Kabatiella caulivora* (Kirchn.) Karak. and *Colletotrichum trifolii* Bain and Essary, two Fungi which cause Red Clover Anthracnose," *Trans Brit. Myc. Soc.*, xiii., 103-140, 1928. S. J. Wellensiek, "Observations on Clover Anthracnose" (trans. title), *Tijdschrift over Plantenziekten*, xxxii., 265-302, 1926).

Most damage is caused by Scorch when red clover is grown alone or with only a few other species, and it is particularly serious when the crop is required for seed, since the fungus attacks the stems with particular vigour at, and after, the flowering period.

In Britain Scorch is confined to red clover, but other species of Leguminosæ have been infected artificially by a culture of the fungus isolated from *T. pratense*. Late-flowering strains of red clover suffer less than early types (W. M. Ware, "'Scorch' or *Glœosporium*

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

Disease of Red Clover," *J. Min. Agric.*, xxx., 833-836, 1923). Among the latter, Italian, English Broad Red, Canadian, and Chilian have been found to sustain severe damage, while an early clover from the Vale of Clwyd proved to be relatively resistant. The hope of minimizing losses lies again in breeding for immunity. Meanwhile, late clovers are to be preferred in districts where the disease is troublesome.

Two diseases which sometimes cause epidemics on red clover are Leaf Spot (*Pseudopeziza trifolii* [Biv. Bern.] Fuck) and Mildew (*Erysiphe polygoni* DC.).

The first covers the foliage with dark circular spots which present a sooty appearance when the infections are numerous. Dark brown apothecia about 1 mm. in diameter appear in the centre of the lesions. Infected leaves ultimately wither and the crop is reduced. *Pseudopeziza medicaginis* (Lib.) Sacc. is a closely related fungus which attacks trefoil and lucerne. In the case of Mildew the leaves are covered by slender superficial mycelium and later become white and powdery with conidia. Cleistothecia are not always produced, as infected leaves soon wilt and dry. This disease, like the leaf spot, is widely distributed over the country. The second growth of clover probably suffers more than the first cut. Mildew attacks several species of Leguminosæ, including white clover, sainfoin, and crimson clover, but the forms upon these hosts are not interchangeable, since the fungus shows marked biological specialization.

Lucerne (*Medicago sativa*) is sometimes destroyed by the Crown Wart disease caused by *Urophlyctis alfalfæ* (Lagerh.) Magn., which is reported as a serious pest in certain parts of North America (F. R. Jones and C. Dreschler, "Crown Wart of Alfalfa caused by *Urophlyctis alfalfæ*," *J. Agric. Res.*, xx., 295, 1920). Fortunately in Britain the disease has a restricted range, occurring only in the three counties Bedfordshire, Kent, and Cambridgeshire (J. Line, "A Note on the Biology of the 'Crown-Gall' Fungus of Lucerne," *Proc. Camb. Phil. Soc.*, vol. xx., part 3, 1921; "Fungus Diseases of Crops, 1920-1921," *Misc. Pub., Min. Agric.*, No. 38 (London), 1922; "Fungus and Allied Diseases of Crops, 1922-1924," *ibid.*, No. 52, 1926). The disease is characterized by pale coralloid outgrowths at the crown, not unlike those caused by *Synchytrium endobioticum* (Schilb.) Pers. on the potato. Infected plants of lucerne are undersized, pale in colour, and short-lived. A waterlogged condition of the soil favours the spread of infection, which usually occurs between September and February. Plants of all ages, except very young seedlings, can be infected. Brown resting sporangia which occur in the warty outgrowths may remain viable in the soil for a number of years. Sickle medick (*Medicago falcata*) has been infected by workers in the U.S.A., but apart from lucerne the Leguminosæ of Britain are immune from this disease, a fact which partly explains the restricted range of the disease in this country.

Among the diseases which cause different types of injury to the leaves of clovers the following deserve mention: Downy Mildew (*Peronospora trifolii* de Bary) on red, white, and alsike clovers and on lucerne; Rust (*Uromyces* spp.) on red, alsike, crimson, and white clovers,

LEGUMES, BREEDING OF HERBAGE (*Continued*)—

trefoil, and sainfoin; Black Blotch (*Dothidella trifolii* [Pers.] Bayl. Elliott and Stans.) on red and white clovers; Violet Root Rot (*Helicobasidium purpureum* [Tul.] Pat.), which sometimes occurs on white clover and lucerne, causing the wilt and finally the decay of plants (W. A. Ware, "Violet Felt Rot [*Rhizoctonia*] of Clover," *J. Min. Agric.*, xxx., 48-52, 1923).

Among the many fungi which attack cultivated grasses, the Rusts rank first in importance. They are annually present in small quantities, but certain seasons are remembered as "Rust years," when the damage to pastures and hay aftermath is exceptionally severe. The conspicuous uredo-sori then produce a universal golden colour in the field, and this is enhanced by the yellowing of the leaves which follows the attack. Numerous species of Rusts contribute to this effect. Perhaps the commonest in this country are *Puccinia lolii* Niels and *P. dispersa* (sens. lat.) Erikss and Henn on the rye-grasses, *P. glumarum* (Schm.) Erikss and Henn and *U. dactylidis* Otth. on cocksfoot, and *P. phlei-pratensis* Erikss and Henn on timothy, but others are no doubt responsible for local outbreaks.

It has been repeatedly observed that grasses, growing in pure species plots for the purpose of seed production or experimental study, sustain more damage from the attacks of Rust and other fungi than those which occur as constituents of the grassland on an ordinary farm. In this connection mention should be made of the Choke disease (*Epichloe typhina* [Fr.] Tul.), which by trapping the inflorescence makes the plant completely barren as far as seed production is concerned. Epidemics of this disease on cocksfoot and timothy have been recorded in the seed-growing areas of Denmark, while pedigree cultures of the same species have suffered considerable damage at the Welsh Plant Breeding Station.

The well-known disease of Ergot (*Claviceps purpurea* [Fr.] Tul.) which frequently attacks rye occurs also on a number of grasses. The significance of this fungus lies chiefly in the poisonous properties of the sclerotia, which replace the ovaries on infected plants. The fungus is fortunately seldom so abundant that poisoning of stock follows, but the danger is one to be kept in view, particularly in hay consisting largely of *Lolium* and *Festuca* species. Sclerotia are common in commercial seed, but the prevalence of the fungus on wild grasses no doubt accounts for most of the outbreaks on farm crops.

Among the numerous diseases of minor importance mention should be made of the Brown Leaf Spot of cocksfoot and meadow foxtail caused by *Mastigosporium album*. This fungus is sometimes an important contributing factor to the condition of grassland known as "winter-burn."

Smut (*Ustilago perennans* Rost.) is a common seed-borne disease of tall oat-grass, and replaces the grain by dusty black spores. The fungus overwinters in the root stock, and is perennial, like the host.

In conclusion it may be said that the damage to grassland by parasitic fungi is an accumulated effect due to a large number of species. It is evident from the nature of the crop that the application of fungicides is not likely to be practicable or economic. It is well that the

LEGUMES, BREEDING OF HERBAGE (*Continued*)—
more important of these parasites should be kept in view by the plant breeder, since their future control depends mainly on the use of resistant strains of herbage plants.
K. S.

LENTILS—For composition and feeding value see Feeding Stuffs.

LETTUCE—See Market Gardening.

LIGNINS—A group of ethoxy- and methoxy-substituted cellulose-like substances appearing in the cell walls of plants with advancing maturity. The carbon content is considerably higher than in cellulose. Jute contains considerable quantities of lignins.

LIME AND LIMING—I. The Materials used for Liming—The word "lime" is used in colloquial agricultural language for a large variety of materials which are applied to the land. There are, however, only six constituent chemical substances, one or more of which is responsible for the suitability of any particular commercial "lime": *calcium carbonate*, $CaCO_3$, is the principal constituent of chalk and of limestones; *calcium oxide* (quicklime), CaO, is the product of "burning" the carbonate, in which process the carbonic acid is driven off as a gas; *calcium hydroxide*, $Ca(OH)_2$, is formed when calcium oxide combines with water during slaking. Most liming materials owe all their value and all liming materials owe part of their value to one, two, or all three of these substances. But there are some liming materials which may also contain one or more of the corresponding compounds of magnesium. These compounds are *magnesium carbonate*, $MgCO_3$, which, along with calcium carbonate, is a constituent of magnesian limestone; *magnesium oxide*, MgO, which is formed along with calcium oxide when magnesian limestone is "burnt"; and *magnesium hydroxide*, $Mg(OH)_2$, which is formed along with calcium hydroxide when burnt magnesian lime is slaked.

Each of these six substances is a white solid. The oxides and hydroxides are soluble to an appreciable extent in pure water. The carbonates only dissolve to any significant extent in water containing carbonic acid when they form solutions of the bicarbonates $Ca(HCO_3)_2$ and $Mg(HCO_3)_2$. On exposure to the air the oxides are slowly converted into hydroxide and carbonate.

The various materials used for liming contain, of course, in greater or less amounts, substances other than these six—as, for example, silica, iron and aluminium compounds—but such additional substances are here to be regarded as innocuous impurities, inasmuch as they play no part in the enhancement of soil fertility.

The commercial products used for liming may be considered in three groups:

(1) *Non-Magnesian "Limes"*—Of these the chief are:

(*a*) *Lump lime*, also known as shell, stone, or cob lime. This is essentially calcium oxide or quicklime, obtained by "burning" chalk or limestone.

(*b*) *Ground lime*, which is the same material after being artificially ground.

LIME AND LIMING (*Continued*)—

(*c*) *Hydrate of lime*, which is essentially calcium hydroxide, and is obtained by slaking lump lime with water, when the resulting hydroxide falls to a fine powder.

(*d*) *Ground limestone* is limestone (calcium carbonate) which has been artificially ground to a fine powder.

(*e*) *Ground chalk* is also calcium carbonate prepared by the grinding of naturally occurring chalk.

(2) *Magnesian "Limes"*—The liming materials which contain magnesium are generally designated in the same way as the non-magnesian materials, and it is not generally possible, therefore, to tell from the designation whether or not a magnesium compound is present. Ground limestone, for example, may be prepared from limestone containing only calcium carbonate, or it may be prepared by grinding magnesian limestone which contains magnesium carbonate in addition. Similarly, lump lime may be obtained by the " burning " of a calcium carbonate or a magnesian limestone.

There is a long-standing belief that magnesium compounds in a lime are detrimental to plant growth, but experimental tests have failed to confirm this belief.

(3) *Waste Limes*—There is a fairly large variety of manufacturing processes from which one or other of the above named calcium compounds, mixed usually with other things, arises as a by-product. Among these by-products probably the chief is Billingham carbonate of lime, which is calcium carbonate containing a fairly large amount of water and small amounts of sulphate of ammonia, and which is a by-product from the manufacture of sulphate of ammonia (*q.v.*). Other waste limes are usually of local interest, as, for instance, waste lime from beet-sugar factories and whiting works, which are valuable mainly on account of their content of calcium carbonate. The waste limes from soap-works, wire-works, etc., may contain undesirable substances, and should not usually be used without specific advice being obtained.

II. The Reason for Liming—It is common knowledge that liming has been practised as far back as any records of agricultural practice go, and through many centuries of farming a vast amount of empirical knowledge of the effects of lime has accumulated. Among these well-established effects the chief are:

(1) The suppression of certain diseases, of which the outstanding instance is Finger-and-Toe in cruciferous crops.

(2) The suppression of certain weeds such as spurrey, sorrel, and mayweed on arable land, and bent grass and woodrush on grassland.

(3) The amelioration of the sticky condition of certain heavy soils with a definite reduction in the plough draft.

(4) The preserving or restoring of some necessary conditions for the growth of certain crops, notably barley, sugar beet, mangolds, legumes, and wheat, which have been found to fail when the soil is short of lime. (See Lysimeters.)

While such knowledge of the visible effects of liming has accumulated

LIME AND LIMING (*Continued*)—

by experience, expedited in later years by field experiment, it is only recently that agricultural chemists and plant physiologists have given serious consideration to the underlying reasons for such effects being consequential upon liming.

So far as the effect of liming upon Finger-and-Toe is concerned, we still do not know the whole truth. In a general way we know that the disease is characteristic of land short of lime, but the application of lime will not necessarily eradicate the disease immediately, although it is almost certain to reduce it. Moreover, when one part of a field is affected by this disease it does not always happen that the lime shortage in that part is any more than elsewhere. The relation of lime to this disease is a matter for further investigation.

The suppression of certain weeds by liming is probably for the most part due to improvement of the crop and the consequent increased competition which the weeds have to meet. In some instances, however, liming may establish conditions which are directly less favourable to the growth of the weed.

The improvement of the physical texture of certain clay soils by lime has become better understood during the last decade. It is primarily the consequence of the coagulation of the soil colloids, which in their uncoagulated state contribute enormously to the stickiness of the soil. This coagulation brings about the bunching or flocculation of the soil particles which admits of freer drainage. (See Soils.) The effect is most pronounced when the oxide or hydroxide of calcium is used, although a small improvement may follow the application of calcium carbonate. It is important to notice that only in certain cases is the stickiness of heavy soils reduced by liming. Other soils which, while undoubtedly sticky, have less pronounced colloidal properties, are not appreciably improved. (See Soil Colloids and Humus.)

The outstanding result of liming is undoubtedly its effects upon the growth of certain crops, and the cause of this has been the subject of a very widespread discussion in recent years. When scientific thought was first brought to bear upon the subject the situation seemed quite clear. All the soils in which the so-called susceptible crops failed and whose fertility is restored by liming were found to be acid, and it was naturally assumed that the cause of the crop failure was acidity, and the function of the lime was to neutralize the acid. Instances were recorded, however, of certain very acid soils in which these crops did not fail, and whose fertility was not appreciably improved by liming. Experimental work in culture solutions also seemed to show that these crops, or at any rate barley which has been used in most experiments, could successfully withstand a degree of acidity as great as that in most acid soils. Hence it has been suggested that some other factor which commonly accompanies acidity may be the toxic substance in soils short of lime, and a great deal has been written of the possible action of aluminium salts. It cannot be said that there is as yet any general agreement as to why the crops in question fail when a soil is depleted of lime. The experimental investigation of the matter is fraught with greater difficulties than

LIME AND LIMING (*Continued*)—

those at first obvious. Considerable difficulties arise, for instance, from the ability of root hairs of plants to alter the state of acidity of the solution surrounding them. Apart from the scientific interest of the subject, the question is one which merits further investigation in the interests of agriculture, since a proper understanding may very well be expected to assist in the study of the economics of liming. (See Plate XVII.)

III. The Detection of Lime Deficiency—In view of what has been said about the observed effects of lime, it will be clear that with comparatively little experience a lime deficiency can be detected if the soil can be seen under a crop. The characteristic crop failures and the characteristic weed flora are the most helpful field indications of lime deficiency.

Sometimes, however, a field has to be considered when no crops or weeds are available, and a number of simple tests have been introduced to expedite the diagnosis of the lime status of soils.

One of the oldest and best known of these tests is the addition to the soil of hydrochloric acid, which, by its reaction with calcium carbonate in the soil, evolves carbonic acid, giving rise to effervescence. While this is perhaps the best known and the longest established test, it must be remembered that the information it gives is very limited. It has generally been assumed that where no effervescence is to be seen, and no calcium carbonate is therefore present, liming is desirable. This, however, by no means follows, since the lime in the soil, which is active in suppressing the unknown detrimental factors called sourness, is combined with the soil particles (see Soils) and will not produce effervescence. The free calcium carbonate is present as what is commonly termed a "reserve of lime," and can by reaction with the soil replace deficiencies as they occur. When, therefore, a soil effervesces freely with acid, it may reasonably be assumed that it does not require lime. If, however, there is no effervescence, that fact in itself does not indicate the extent or even the existence of lime *deficiency*.

A number of tests which have been more recently introduced give more information than the old acid test, and incidentally are easier to carry out. Many of these are tests with coloured indicators. When a little of the solution of the indicator is put upon the soil in a suitable porcelain dish and the liquid afterwards allowed to drain away, the colour of the liquid is a fair indication of the lime status of the soil. Another test which has been used during the last few years is the addition to the soil in a test tube of an alcoholic solution of potassium thiocyanate. The solution is coloured red by soils deficient in lime. (See Acid.)

IV. The Determination of the Extent of Lime Deficiency—It is manifestly not sufficient merely to know that a soil is short of lime. If lime has to be applied, some measure of the extent of the deficiency is needed. During the last ten to fifteen years soil chemists have devoted a great deal of attention to the determination of this deficiency, with the result that a large number of "lime requirement" methods

PLATE XVII

BARLEY CROP, JUNE 5, 1920, FIELD 40 (LOOKING SOUTH).

Foreground—Land chalked in 1911. Middle—Land not chalked. Background in same field—Oats, not on experimental plots.

(By permission of the Yorkshire Council for Agricultural Education and the University of Leeds.)

To face p. 658

LIME AND LIMING (*Continued*)—

have been suggested, and some of these have come into use for advisory purposes. The methods vary very much in their detail, but they all depend fundamentally upon getting some measure of the amount of lime or some other base which the soil can take up from solution. They are unsatisfactory inasmuch as they are all arbitrary; that is to say, the results which they give vary according to the conditions under which the determination is carried out. Different methods give different results, and different workers may obtain different results by the same method if there is much difference in the detail of their procedure. This does not mean, however, that the methods are useless, and when they are coupled with some practical experience in the field they do give a valuable guide to the amount of lime which may be economically applied. But they must be used along with other considerations. Thus, for example, if a determination indicates a lime requirement of 10 cwts. quicklime per acre, it does not automatically follow that it would be wise and economical to apply that amount. If the soil is very heavy such a lime requirement may not be a serious matter at all, and it may not be worth while to lime for years to come, whereas if the soil is very light the state of sourness may be serious, and it may be desirable to lime in excess of the lime requirement in order to establish some reserve to meet the inevitable loss of lime in the drainage water. Again, if lime is being considered mainly for the purpose of preventing Finger-and-Toe, it is generally desirable to exceed the lime requirement.

In computing the amount of lime to apply, the farmer should consult the advisory chemist.

V. The Choice of a Source of Lime—There are a number of factors to be taken into consideration in deciding which of the available commercial forms of lime shall be used in any particular case. The choice between calcium carbonate and calcium oxide will very largely be determined by the relative costs. Roughly speaking, 2 tons of carbonate are required to bring about the same effect as 1 ton of oxide, and the cost of carting is accordingly higher. Unless, therefore, the relative cost of the carbonate is low enough to cover this, some form of oxide will ordinarily be chosen. However, there are cases in which other considerations than those of cost arise. On very light soils it is preferable to use carbonate, the effects of which appear to be maintained for a longer period than those of the oxide or hydroxide. Again, if lime is being applied in the hope of reducing the stickiness of a heavy soil, the oxide should be used rather than the carbonate.

When some form of oxide is used, the decision between the cheaper lump lime and the more expensive ground lime will largely be determined by the amount to be applied. In applying lime every effort should be made to get the lime as uniformly distributed through the soil as possible, and when this has to be done with a small quantity, ground lime must be used and drilled. If the amount to be applied per acre is of the order of 2 tons or more, then lump lime can be used and put out in heaps and allowed to slake and break down in the field.

LIME AND LIMING (*Continued*)—

The choice between the oxide and hydroxide is essentially a decision as to whether it is worth while to pay more for a material more convenient to handle. Hydroxide is more expensive for the same effective quantity of lime, but whereas the oxide absorbs moisture from the air with an incipient slaking which causes bags to burst, no difficulty of that kind arises with the hydrate, which is in a fine, dry form admirably suited to drilling.

In using the various forms of lime it must be remembered that 11 cwts. of the oxide is equivalent to 15 cwts. of the hydroxide, and to 1 ton of the carbonate.

VI. The Application of Lime—In liming arable land the time of application must be considered in relation to the crops constituting the rotation, and also in relation to the extent of the lime requirement. If the lime requirement is small the application may suitably be made a month or so before the sowing of the next *susceptible* crop. In a rotation, for instance, in which swedes follow oats, the liming can be delayed until some time before the sowing of the swedes, as oats are not seriously affected by small lime requirements. Where, however, the lime requirement is large, most crops, excepting perhaps rye and potatoes, are liable to be affected, and liming should be carried out as soon as possible.

The liming of grass land calls for special mention. It is particularly important to maintain the lime status of the grass land of dairy farms, as a deficiency of lime in either the grass or the hay may affect the composition and value of the milk.

When the lime requirement of grass land becomes very high, partly decomposed grass accumulates as a "mat" on the surface, which may in time become several inches thick. In this event it is necessary to tear up the mat with weighted arable land harrows, preferably in the winter when the mat is wet, prior to a heavy liming with lump lime. The lump lime is best put out in heaps to slake, and then spread before it becomes too wet. N. M. C.

LINSEED CAKE—For composition, feeding and manurial values, see Feeding Stuffs.

LIQUORICE (*Glycyrrhiza glabra*)—The liquorice of commerce is obtained from the root of the liquorice plant, which is a native of Asia Minor and Southern Europe, but is cultivated extensively in the United States, on the Continent, and, to a lesser extent, in Great Britain, where it is chiefly confined to the Pontefract district of Yorkshire.

Cultivation—In order to obtain roots of commercial size, the plants are permitted to stay on the same piece of land from three to five years, but as a rule four-year-old plants are those which are lifted for sale. The soil most suitable for liquorice is a very deep, medium loam, and the land must be very thoroughly prepared before planting. From thirty to forty loads of farmyard manure per acre are usually applied to the land, which must be deeply worked. The plants, which consist of runners and the crowns of mature plants taken up the

LIQUORICE (*Continued*)—

previous lifting season, are set out alternately with a dibber on flattened ridges about 4 ins. high and 3 ft. apart, two rows being set out on each ridge. During the first two years the land between the ridges may be intercropped with salad and other vegetables, but the plants will require the whole of the available space during the third and fourth years.

The lifting of liquorice roots, which usually takes place during October and November, is a very elaborate and expensive business, costing as much as £60 an acre. As the roots run up to 4 ft. or more in length, trenches require to be dug along the sides of the rows to enable the roots to be removed without breakage or damage. When raised, the roots are trimmed of runners and small roots, the crowns cut off, and then made into bundles weighing 3½ lbs.

These bundles are in turn made up into 1 cwt. bales, in which condition the liquorice roots are sent to market. All fragments of roots, except the runners and crowns, which are saved for planting, are usually sold to manufacturing chemists and confectioners.

The yield of large roots on good land is estimated at 2 tons per acre plus a few cwts. of fragments, or offal as they are termed. One cwt. of roots is stated to yield 30 lbs. of commercial liquorice. A great deal of the English crop is sold for chewing, and for this reason is said to make higher prices than when sold for factory purposes.

No change of soil is necessary for liquorice, and after the roots are lifted it may be prepared again for planting.

LOGANBERRY—See Soft Fruits, under Fruit.

LUCERNE—Introduction—Lucerne (*Medicago sativa*) is probably the oldest forage crop in common use. It was known in Persia in the earliest times, and it seems to have spread West from there, first through Europe and then to America, where it is known as alfalfa, a word of Persian origin meaning "the best fodder."

No crop has been more widely "boomed" than lucerne, and yet to the world's enormous acreage under the crop Great Britain contributes only something like 65,000 acres, and of these nearly one-quarter are grown in Essex.

Lucerne, on account of its high feeding value, drought-resisting properties, and soil-enriching character, is one of the most valuable forage crops which can be grown by the stock farmer. To dairy farmers in the eastern counties of England it has a particular value in supplying an abundance of green, luscious food at a time of the year when pastures may be parched and bare.

Farmers in Canada, America, and New Zealand have been quick to realize the value of lucerne as a food for all classes of livestock, but the crop makes but little headway in England, largely because its cultivation and management are not widely understood. It cannot be stated too definitely that if the habit and requirements of the plant are understood, no crop enjoys a wider adaptability to conditions of soil and climate in Great Britain.

Lucerne will flourish on light land as well as on heavy; the sun will

LUCERNE (*Continued*)—

not dry it out, and frost will not injure it seriously; it thrives in a dry climate, but it is not unsuitable for districts of moderate rainfall.

For successful cultivation of lucerne there are a number of factors which must be borne in mind, and the omission of any one of these may mean failure.

Soil—As already stated, lucerne will grow on widely different soils, but three conditions must be fulfilled: (1) That the soil is not acid—that is, short of lime; (2) that there is a good supply of organic matter, or, in other words, the soil must be in "good heart"; (3) that the drainage is adequate, and there is no tendency for the soil to become waterlogged.

Where these conditions are satisfied lucerne seems to grow well, and it would be unwise to say that any particular soil is especially suitable for the cultivation of the crop.

Varieties—A number of varieties has been known for many years, and there are records of variety trials extending back over a long period.

Most varieties owe their names to the country of origin, but each so-called variety is a mixture of a number of different strains, and modern workers are now attempting to isolate the most desirable strains within the variety rather than making simple comparisons of different varieties. (See Legumes, Breeding of Herbage.)

The more common varieties are **English, Provence, Hungarian, Marlborough, Hunter River, South African** and **Grimm.** Evidence is rather in favour of English for British conditions, but as so little of the crop is seeded in this country, the seed is so expensive as to be almost prohibitive. Provence is the most popular variety and probably the most reliable, though quite good results have been obtained from Grimm. Many growers mix the seed of two or more varieties with apparently good results, but no variety should be selected unless it is definitely known that the climate is suitable for it.

Preparation of Seed-Bed—Preparation of the soil must begin a long time before it is intended to sow the seed—that is to say, previous crops should be selected which will permit of the thorough and deep tilling of the ground, subsoiling if necessary, and the destruction of all weeds. Crops like potatoes, sugar-beet, and other root crops are the most suitable for this purpose. The tilth required for lucerne is identical with that required for clover: the soil must be fine but solid, and absolutely free from weeds. The subsoil must be well-drained, and if there is the slightest suspicion of soil acidity, lime must be applied.

Manuring—If lucerne follows a crop such as potatoes the soil will probably have received a liberal application of farmyard manure, than which there is no better preparation. Before drilling the seed, phosphates and potash should be applied at the rate of 4 to 5 cwts. superphosphate and 4 cwts. kainit per acre. The actual source of phosphates and potash will, of course, be governed by the type of soil and climatic conditions. It is unwise to defer the application of these

LUCERNE (*Continued*)—

manures until the plants are " up," as the crop should be given every possible opportunity of establishing itself right from the beginning. In the early stages of growth an application of 1 cwt. per acre of a nitrogenous manure may be beneficial, but is probably unnecessary in later years.

Inoculation of the Seed—Experience in the inoculation of lucerne seed prior to sowing is most varied. Prior to the research work carried out by Thornton at Rothamsted, inoculation could be said definitely to produce very unreliable results.

About 1924, however, Thornton introduced a simple and effective method of inoculating the seed with the bacteria (*B. radicicola*) associated with lucerne, and most striking results have been obtained on soils which previously would not grow the plant. (" The Growing of Lucerne," Rothamsted Conferences. Ernest Benn, London.) It cannot be said that in all cases inoculation produces an increased crop; in fact, in many cases it makes no difference at all. At the same time the cost of inoculating the seed before sowing amounts to only a shilling or two an acre, and it would therefore be unwise for any farmer to attempt to grow lucerne on a doubtful field without first inoculating the seed. The risk of failure is so great, and the expense and trouble of inoculation so infinitesimal, that there seems to be no logical argument against it.

Up to 1929, cultures for the inoculation of lucerne seed were sent out by the Rothamsted Experimental Station, but the rights to distribute these were handed over to Allen and Hanburys, Ltd., who are now recognized by the Royal Agricultural Society for England as the official distributors.

Very full directions for the inoculation of the seed are sent out with the cultures of the nodule bacteria.

Seeding—Lucerne seed may be sown either with or without a cover crop, in spring or in late summer, in wide or narrow rows, or it may be sown broadcast. A heavy seeding may be used, or a light one. There are advantages and disadvantages in each method, and the grower must decide for himself which method is best suited to his own particular conditions. If the seed is sown in a cover crop, the cover crop should be light and sacrificed considerably to the interests of the lucerne. If spring sowing is favoured, the lucerne seed should be sown as early as possible and at right angles to the cover crop. On the heavier soils, it is probably best to bare fallow the ground all summer, and then to sow the seed without a cover crop about the end of July in a thoroughly clean seed bed. A " take " is nearly always certain by this method.

If the seed is sown in drills about 10 ins. apart, it is possible to practise inter-cultivation and keep weeds in check. Almost equally effective, however, seems to be the less expensive methods of either drilling the rows close together or broadcasting the seed and keeping the land clean by severe harrowing or " discing " in spring and autumn. It is impossible to kill lucerne by cultivations, and experiments have

LUCERNE (*Continued*)—

shown that it is greatly benefited by constant cultivations. The seed must not be sown too deep; about 1 in. below the surface of the soil is considered the optimum depth.

The seed rate per acre is also very variable, and is dependent somewhat on the method of drilling. If, however, the seed is sown in spring under a cover crop, about 20 lbs. per acre should be sufficient. This amount might be increased to as much as 30 lbs. per acre where it is to be sown on bare ground in late summer. The heavier seedings make inter-cultivation less expensive, and the herbage is of better quality; whilst with the lighter seedings individual plants are stronger, develop a stronger rooting system, and consequently stand longer.

Where a crop is being sown for the production of seed and not fodder, a very light seeding indeed should be used.

Whether drilled or broadcasted, the seed should be well covered by harrowing with a light set of harrows.

According to Hill ("Culture of Lucerne," Whitcomb and Tombs) lucerne transplants well, but so far as English conditions are concerned transplanting on a large scale must be uneconomic.

Lucerne is usually sown as a pure crop, and it is advisable that it should be. It can, however, be sown with success along with grasses, such as perennial rye-grass, or cocksfoot. A mixture of cocksfoot and lucerne, sown on the chalk lands in south Cambridgeshire, gave heavy cuts of hay by the end of May, and for the rest of the season provided excellent pasturage for sheep.

Management—If lucerne is sown in spring under a cover crop, except in exceptional circumstances, no cultivations are required until the following spring, when it should be horse-hoed, and probably rolled.

If sown in spring or late summer without a cover crop, it will be necessary to cut it when the plants are from 6 to 8 ins. high. This is necessary not only for weed control, but to encourage the development of the rooting system of the plants. With late autumn sowings it may be wiser to let the plants die down and not use the mowing machine, but, generally speaking, it is better practice to run the machine over if possible.

It must be remembered that lucerne is a perennial, and that the first year is spent more in the development of root than in the production of herbage. Growers, therefore, if dissatisfied with the appearance of the crop in the first year, should hesitate before deciding that the crop has failed, for a crop which looks like a failure in spring frequently develops into a full plant by autumn.

In the first season of actual production the crop should be mown not oftener than twice. If there is a third "cut," it should not be mown, but left to die down. This is most important, as over-cutting in the first year will mean reduced yields of fodder in subsequent years.

Cultivations in autumn and spring should be severe. Some growers who have planted lucerne in wide rows use a plough between the rows each winter with marked success. Sustained efforts should be made to keep weeds and grass in check, and, provided the crop is kept clean,

LUCERNE (*Continued*)—

lucerne will remain productive for from eight to ten years. It takes three years for it to reach maximum production.

Harvesting—After its first year, lucerne should normally produce three cuts of fodder each season, two of which may be made into hay and the third fed green; in specially favoured districts more "cuts" may be obtained. The great value of the crop as hay lies in the leaves, which contain from 75 to 80 per cent. of the protein of the whole plant. Haymaking is, therefore, a most important operation. Cutting should begin just before the lucerne is in bloom, and if left until later many of the leaves will be lost, and the weight of subsequent cuttings reduced.

After cutting, the crop should be left in the "windrow" as short a time as possible, and then put into small "cocks," from which it is stacked. The fewer handlings, consistent with good curing, the better the hay will be. There is a danger of heating if the hay is carted too soon, but a slight heating in the stack is not a disadvantage.

Lucerne, of course, need not be made into hay. It may be cut and fed green as a soiling crop, or used for silage. (See Ensilage.)

Seed Production—For a number of reasons the first "cut" should not be saved for seed. The second "cut" is the one to save, and cutting should be done when most of the seeds are hard but not ripe enough to shell. If the weather is "drying," the cutting should be got into the "cock" as soon as it is fit, but it must not be stacked until thoroughly dry, for heating in the stack will destroy the vitality of the seed. The seed should remain in the stack for at least one month before threshing with an ordinary clover hulling machine.

The yields of seed are variable, and may be anything up to 13 bushels per acre, but the average is just about half that amount.

Food Value—The feeding value of lucerne hay naturally varies with the degree of maturity of the crop when cut, and with the methods adopted in haymaking. The chemical analysis of lucerne hay cut at different stages is given in "Rations for Livestock," published by the Ministry of Agriculture, and shows it to contain more protein than any other kind of hay. Lucerne hay, therefore, saves the farmer a certain amount in the purchase of feeding stuffs rich in protein. As a soiling crop lucerne is just as valuable. McIntosh ("The Growing of Lucerne," Rothamsted Conferences, Ernest Benn, London) estimates that one acre of lucerne, cut green, will provide about 40 lbs. of fodder daily for seven cows, for almost three months during the driest part of the year. (See Feeding Stuffs.)

Farmer Giles ("Manures and Manuring") estimates that an acre of lucerne will produce enough green fodder to keep a cow for sixteen months, or to keep four cows well supplied during the four summer months.

There is to-day a greater appreciation of the feeding value of lucerne, and the acreage under the crop is gradually extending. When the cultivation of the crop and its high feeding value are properly ap-

LUCERNE (*Continued*)—

preciated, there should be a rapid extension in the growth of lucerne in Great Britain.

(For diseases and insect pests of lucerne see Diseases of Pasture and Forage Crops, under Legumes, Breeding of Herbage; and Insect Pests of Root and Forage Crops, under Turnips and Swedes.)

References.—Percival, "Agricultural Botany," Duckworth and Co., London; Clark and Malte, "Fodder and Pasture Plants," Government Printing Bureau, Ottawa; Voorhees, "Forage Crop," Macmillan and Co., London; Shaw, "Forage Crops," Orange Judd Company; Wilson, "Our Farm Crops," Blackie and Son; Gresham Publishing Company, "Farm Crops"; Farmer Giles, "Manures and Manuring," Arthur Pearswell; Hill, "The Culture of Lucerne," Whitcomb and Tombs; Coburn, "The Book of Alfalfa," Orange Judd Company; Rothamsted Conferences, "The Growing of Lucerne," Ernest Benn, Ltd., London; "Stephen's Book of the Farm," Blackwood and Sons; Essex County Farmers' Union Year Book, 1930.

J. C. L.

LUPINS—The lupin as an agricultural plant was well known to the Romans; the writings of Pliny, Columella, Palladius, Theophrastus, and others contain observations which show that the growth and value of lupins was thoroughly understood in their times.

The lupins grown in this country as an agricultural crop are annuals; and no case is known of the perennial lupin being grown in England for any purpose other than that of an ornamental plant. In Bohemia perennial lupins (*Lupinus perennis*) have been grown on poor soils in mixture with forest trees, and it was found that the forest trees made much better growth owing to the lupins assisting in retaining moisture, and enriching the soil in nitrogen. It was also found that the perennial lupins assisted in smothering weeds, especially heather (Nawratilk, *Centralblatt für das gestamte Forstwesen*, Vienna, 1916).

In the Orkneys, large areas of blue lupins grow wild amongst the heather and are grazed by sheep. It is interesting to note also that seed sent from the Orkneys to Suffolk was much smaller than that of the lupins grown in the latter county.

Soils—A comparatively small area of lupins is grown as an agricultural crop in this country. Lupins are essentially a light land crop; in fact, they are practically the only leguminous crop which can be grown on light land which is deficient in lime.

On the Continent, especially in the extensive light land areas of Germany and Holland, they are better known and appreciated than in this country.

Lupins have been grown in Suffolk, on very poor light land, for a long period. In 1859, Mr. Crisp of Butley, Suffolk, grew them successfully, and an account of his experiences appears in the *Journal of the Royal Agricultural Society*, 1859. Since that time there has been an appreciable area of lupins cultivated annually in Suffolk, where they are used for green manuring, for folding sheep, and for seed production. The great value of lupins lies in their ability to grow

LUPINS (*Continued*)—

luxuriantly on poor light land, where most other crops will not grow. Being leguminous plants, they accumulate nitrogen from the air, and hence greatly enrich the land.

As far as the writer is aware the inoculation of lupin seed has not been tried in this country. In all cases under his observation, where lupins were grown in suitable soil they produced abundant growth, and numerous nodules without inoculation.

By taking advantage of their nitrogen-accumulating qualities, Dr. Schultz of Lupitz, Saxony, succeeded in greatly improving poor sandy soil (Dyer, *J.R.A.S.E.*, 1896).

The lupins were grown in rotation with other crops, the latter receiving mineral manures, lime, and phosphates. It was found that the lupins greatly increased succeeding crops. Thus, in one case after lupins ploughed in, 9 tons of potatoes per acre were obtained, whereas with 8 tons of farmyard manure the yield was 6 tons per acre only. In another case after lupins ploughed in, 27 bushels of rye per acre were obtained, whilst after potatoes heavily manured with artificials only 12 bushels resulted.

Dowling in Nottinghamshire (*Report on Field Experiments*, 1921 and 1922, Notts Education Committee) tested the effect of lupins upon the succeeding crop. Oats after lupins yielded 58 bushels per acre, and after buckwheat they produced only 12 bushels per acre. In Suffolk lupins are generally recognized as having an extremely beneficial effect upon the succeeding crop, provided that crop is one suited for light land of an acid character, such as that upon which lupins are generally grown.

Recently they have been included in the light land rotation adopted at the Light Land Experimental Station at Tunstall, Suffolk, this rotation being lupins (ploughed in), rye, potatoes or sugar-beet (the latter is only successful on land containing sufficient lime), and oats. The land is of an extremely poor character, and produced hardly any crop for the three years immediately previous to the commencement of the experiments. By the use of phosphates and nitrogen on the roots, and small dressings of nitrate on the cereals, it has been found possible to raise the general level of the crops obtained to a much higher point than was anticipated. Thus, crops of 34 cwts. of rye, 25 cwts. of oats, 14 tons of potatoes, and 12 tons of sugar-beet per acre have been obtained, a result due in part to the green lupin crops which have been ploughed in. No farmyard manure has been used, as one of the objects of the experiment was to ascertain whether satisfactory crops could be obtained on this poor soil by growing lupins as the leguminous crop, to enrich the soil in nitrogen and humus (see *J.R.A.S.E.*, 1930). It may be mentioned that even when the lupin crop is saved for seed, large quantities of the leaves fall to the ground, where on ploughing in they ultimately act as manure.

Varieties—Blue Lupin (*Lupinus hirsutus*) is the variety grown most commonly in England; it grows about 3 to 3½ ft. high, and makes a dense mass of green herbage. When grown on light land

LUPINS (*Continued*)—

in Suffolk, it generally ripens its seed satisfactorily, but in a wet season such as 1927 the amount of seed produced may be very small. Under wet conditions its vegetative development is excessive and very little seed is obtained. In a dry year it may produce a good yield of seed, and in 1929, 24 cwts. of seed per acre was obtainable at Tunstall Experimental Station. This, however, is exceptional, and a more usual yield is from 15 to 20 cwts., which must be regarded as good when judged in conjunction with the poverty of the land on which the crop is grown usually.

The seeds of the blue lupin are a little larger than a maple pea, and are mottled grey in colour; they are very bitter to the taste.

Giant White Lupin (*Lupinus albus*) has been grown in Suffolk frequently from imported seed. It produces a much greater bulk of greenstuff per acre than the blue lupin, sometimes attaining a height of 6 ft.; it is, however, somewhat more subject to mould. The seed also is dearer, and there is no record of its being harvested successfully in England. An attempt was made in one case to harvest it, but it ripened too late. However, if drilled early on very light sandy land, it might ripen and be harvested in a dry year.

Large white lupins are quite different to blue lupins in appearance; they produce thick, solid, unbranched stems at the base, whilst above they throw out smaller branches bearing white-flowered inflorescences. The seeds are large, white, and flat.

As the saving of blue lupins for seed is sometimes fairly profitable, it is on the whole perhaps as well to cultivate that variety, even although it may not produce quite so much greenstuff as in the white lupin for ploughing in. Further, the folding of sheep on white lupins is apparently more dangerous than on blue lupins.

Yellow Lupin (*Lupinus luteus*) is grown extensively on the Continent. When grown in Suffolk the yellow lupin was about the same height as the blue lupin, but it did not appear to possess any advantage over that variety. The yellow lupin is somewhat more branched at the ground than the blue lupin, and the branches are borne more horizontally.

Long ("Plants Poisonous to Live Stock," 2nd edit., Cambridge University Press) states that this variety is more poisonous to sheep than the blue lupin.

There is no record of yellow lupin seed being saved in Suffolk. It has been stated that the seed ripens late and is consequently more difficult to harvest than that of the blue lupin.

Wisselink (*Tidschr. der Ned. Herdemig.*, September 1st, 1922) recommends planting a mixture of blue and yellow lupins for green manuring, as owing to the slightly different habit of growth, a denser mass of green material is produced for ploughing in. Yellow lupins do not make such rapid growth in the early stage as the blue kinds.

Ecology—The lupin is essentially a light land plant, and will grow well on the poorest sand, provided there is enough moisture to germinate the seed. On fairly good light land it tends to produce

LUPINS (*Continued*)—

very heavy crops of greenstuff, and the seed may not ripen very well. The lupin is remarkably tolerant of soil acidity and is the only commonly grown leguminous plant which will make satisfactory growth on really acid soil. The large white lupin is apparently rather less tolerant of soil acidity than the blue variety. There is a tradition that an abundant supply of lime in the soil is definitely harmful to lupins, and this is very likely the case. Nevertheless it is possible to have a soil rather too acid to obtain the maximum growth. At Tunstall a soil with a P_H of 5·8, no carbonate of lime present, and a lime requirement (by Hutchinson and McClennan's method) of 27 cwts. per acre will grow lupins very well, but slightly better growth is obtained after an application of 5 tons of chalk per acre. It must not be inferred from this that the presence of much lime in the soil is desirable. On the contrary, modern evidence supports the ancient tradition that an abundant supply of lime is harmful. The Tunstall soil mentioned above contained only about 0·2 per cent. of lime even after the application of 5 tons of chalk per acre, and probably that percentage is ample for the requirements of lupins.

Manuring—It appears that lupins are largely independent of manure, and repeated trials with manures have failed to give any obvious response. If it is considered desirable to apply artificial manures, a small dressing of phosphates and potash is the most suitable.

Sowing—When grown for seed, blue lupins are drilled in April or early May at the rate of 7 to 9 stones per acre; if drilled earlier the crop may suffer from frost. The seed should be tested before drilling as it is rather apt to be of low germination.

When grown as a green manuring crop or for folding, lupins may be drilled at any time up to the middle or even to the end of July. August is rather too late in a normal season, although there is a case on record, in Suffolk, of white lupins drilled on August 16th on rye stubbles growing 15 to 18 ins. high and giving very good results as green manure. The land on which they were ploughed in grew a better crop of oats than another part of the same field manured with 10 loads of farmyard manure per acre.

There is usually ample time to get a crop of lupins for ploughing in or for folding, after sheep-feed of any kind fed off in June, or after trifolium or trefoil mown for hay, and heavy crops may be obtained in this way provided there is sufficient moisture in the soil.

Cultivation—This is very similar to that for spring beans, except that the crop is drilled later. When there are many seed weeds, such as spurrey, it is better to drill in rows 12 ins. or more apart, to permit of horse-hoeing. A dense mass of spurrey is inimical to lupins as probably to every other crop.

When grown for green manuring the crop, if very tall, may be rolled before ploughing in. As a rule, however, by attaching a chain to the plough it is possible to drag the dense mass of greenstuff under without rolling. When grown for seed the crop may be cut with either the side delivery reaper or the binder, preferably when the dew is on

LUPINS (*Continued*)—

the plant, to avoid the seed shelling. The lupins hang together fairly well and really do not need to be tied up; in addition the spiny pods are apt to injure the canvases of the binder. The seed should be thoroughly dry before carting.

Value for Stock—Lupins contain poisonous principles. Kellner ("The Scientific Feeding of Animals") states that fodder from lupins always has a heating effect, and in some years all parts of the plant contain a deadly poison. This, he states, is a protein-like substance probably due to the action of some fungus which, favoured by the weather, emigrates to the plant.

An investigation by Sollman ("Lupins as Poisonous Plants," *U.S. Dept. of Agric., Bull.* No. 405, Washington, December 5th, 1916) showed the presence of alkaloids in American lupins and pointed to the probability that most if not all of the poisoning of livestock was due to alkaloids and not to a hypothetical substance called ictrogen. The latter substance has been considered by certain investigators (Kuhn, Roloff, Arnold, and Lenke) to be the cause of the trouble in northern Germany. The alkaloids considered by some to be present in lupins are toxic or fatal if a sufficient quantity of the plant is consumed, but they are harmless if the consumption is below a certain limit. Up to this point the lupins may be a useful food.

The American authors referred to above state that the actual cause of death when it occurs from lupin poisoning is paralysis of respiration. In the treatment of lupin poisoning good results were obtained from potassium permanganate and from tea.

Lupins do not appear to be invariably poisonous, but only under certain conditions which are not too well defined. Cheshunt and Wilcox give the symptoms as acute cerebral congestion with great mental excitement, the sheep rushing about and butting into things; following is a stage characterized by irregularity of movement, violent spasms, and falling fits. The convulsions resemble to some extent those caused by strychnine. It appears that lupins are much less poisonous to sheep than to other farm animals, and in spite of the somewhat alarming accounts of loss from poisoning from various parts of the world, the Suffolk farmer has no hesitation whatever in folding his sheep upon blue lupins, provided certain precautions are observed (see A. W. Oldershaw, "Lupins and Light Land," *J. Min. of Agric.*, July, 1925; also A. W. Oldershaw, "The Value of Lupins on Poor Light Land," *J. Min. Agric.*, January, 1920).

It is important to commence folding lupins gradually, especially if seed development has reached an advanced stage. The sheep must not go on to the lupins when hungry or they will consume too much. An experienced shepherd, however, will usually take all necessary precautions. It is undesirable to fold pregnant ewes upon lupins. Certain experienced Suffolk flockmasters who fold lupins have informed the writer that they have never lost any sheep through lupin poisoning.

Long (*l.c.*) points out that many sheep have been affected by lupin poisoning in Germany, the most harmful species being the yellow

LUPINS (*Continued*)—

lupin. With care, however, the danger under British conditions is very small. Mr. S. R. Sherwood, the well-known Suffolk sheep breeder, speaking at Derby in 1921, referred to the value of the lupin. He said: "It is not high-class feed, but it has this great advantage: it will flourish on very poor light land. No stock with the exception of sheep will eat it, and even they will only nibble it for the first day or two, but when accustomed to it, they will eat it readily. I know no better crop to plough in as green manure."

Lupins may be grown mixed with oats and vetches for sheep feeding; vetches, rape, and lupins also make a good mixture (see A. W. Oldershaw and John Porter, "British Farm Crops," E. Benn, Ltd., London).

One bushel of lupins, 2 lbs. of rape, and 2 lbs. of white turnip seed per acre is useful for June and July sowing. Half a bushel of buckwheat and 1 bushel of lupins also makes a good folding mixture for very light land. When grown with other plants the danger from poisoning is correspondingly reduced. Lupins, and lupins and buckwheat mixed, have been made into silage in this country and fed to sheep without ill effects.

The following are analyses of lupin, and lupin and buckwheat silage:

	Lupin Silage.	*Lupin and Buckwheat Silage.*
	Per Cent.	Per Cent.
Moisture	83·46	80·87
Oil or ether extract	1·25	1·53
Albuminoids ..	3·15	3·46
Carbohydrates ..	4·13	6·23
Fibre	5·94	6·48
Ash	2·07	1·43

When blue lupin seed is very cheap, as is sometimes the case, it may be fed to sheep. About $\frac{1}{3}$ lb. per head, daily, appears to be the maximum quantity which can be fed with safety; the grain, however, should not be fed to pregnant ewes.

Sheep appear to be the only farm animals to which lupin grain in its untreated state may be fed with a reasonable degree of safety. Various processes are known on the Continent whereby the poisonous properties may be removed from the lupins. After trying four processes at the Janikow starch factory in Pomerania, it was found that suitably treated lupins constituted an excellent food for man and beast. The tests were made at the request of the "Association for encouraging Lupin Cultivation." In the first series of experiments the best results were given by the Thoms process, using hydrochloric acid. In this case the residual content of alkaloids of the de-bittered lupins when dried was 0·029 per cent., whereas with the other three processes it was more, being 0·1 per cent.

At the pig-feeding station at Ruhlsdorf, pigs of all ages have been fed with lupins. Yellow lupins were softened for twelve hours in hot water, in a special steamer, then steamed for one hour, and afterwards washed for twenty-four hours in several changes of water. The resulting material from which the poison had been extracted was mixed

LUPINS (*Continued*)—

with steamed potatoes and the cold mixture given to pigs *ad lib.*, with very favourable results.

At the Würtemberg Agricultural Experimental Station, during 1920-21 lupins were rendered free from bitterness by Bergells' method, using common salt. The conclusion was reached that lupin products, deprived of their bitter flavour, form an excellent protein feed which can be easily kept for a long time, is very digestible both for ruminants and swine, and is almost equal to soya cake for milk production.

According to Kellner, the proportion of albuminoids in lupin grain varies from 29 per cent. for white and blue lupins to 38 per cent. for yellow lupins.

On an average lupins contain about 5 per cent. of nitrogen, hence the manurial value of a badly harvested sample would be appreciable. If it is assumed that the nitrogen present is rather less valuable than that in sulphate of ammonia, the value of the material for manurial purposes may be taken at, say, £2 to £2 10s. per ton. A. W. O.

LYSIMETERS, OR DRAIN GAUGES—Lysimeters, or drain gauges, measure the amount of drainage which percolates through the soil, and hence by taking the difference between the rainfall and the amount of drainage so measured they give a measure of the amount of water which has been evaporated from the soil or used by crops. Lysimeters have been used by water engineers to obtain a measure of the proportion of the rainfall which passes to the underground water supplies, and have also been used in agricultural investigations. Three drain gauges were constructed by Lawes and Gilbert at Rothamsted in 1870; each of these is one-thousandth of an acre in area, and consists of a block of undisturbed soil enclosed water-tight by masonry having a perforated iron base through which the drainage water escapes to be caught in suitable collecting vessels. The Rothamsted drain gauges are uncultivated, unmanured, and uncropped, and have been used to measure the proportion of the rainfall which percolates through different depths of soil, the blocks of soil enclosed being, respectively, 20, 40, and 60 ins. deep. It is found that on the average nearly one-half of the rainfall percolates through the soil, and that there is little difference in the amount whether the drain gauge is 20, 40, or 60 ins. deep. In the winter months it is found that the drainage is as much as 80 per cent. of the rainfall, while in the month of August it falls, on the average, to about 20 per cent.

A few years after the drainage measurements began at Rothamsted, measurements of the nitrates removed from the soil in the drainage also began to be made. These show the amount of nitrate produced by nitrification and washed through an uncultivated, uncropped, and unmanured soil; they do not show what would be removed from the soil by drainage either under natural undisturbed conditions where it is covered with natural herbage, or under agricultural conditions where it is cropped and manured.

Drain gauges were constructed at Craibstone, Aberdeenshire, the experimental farm of the North of Scotland College of Agriculture, in

LYSIMETERS, OR DRAIN GAUGES (*Continued*)—

1914. As at Rothamsted, they are three in number, and each one-thousandth of an acre in area. They consist of undisturbed blocks of soil enclosed in large slate slabs joined together water-tight, the drainage being collected through holes bored in the bottom slabs. The Craibstone lysimeters are each 40 ins. deep, and are cultivated and cropped in the ordinary rotation of the district. Not only is the drainage water measured, but all the constituents washed through in the drainage, whether in solution or in suspension, are estimated, and in this way a measure is obtained of all the bases, potash, soda, lime, etc., and of all the acids, nitric, hydrochloric, sulphuric, etc., washed from the soil. The gauges are therefore used to measure, under conditions of cultivation and cropping which are made as nearly as possible similar to those commonly used in the district, the amount of the rainfall which passes through the soil, and the amount of ingredients of value which are washed by it from the soil at all seasons of the year.

One lysimeter at Craibstone is unmanured; another is manured with dung and artificials given in such amounts as might be used by a farmer who is treating his land well; the third is similarly manured, and receives in addition a dressing of lime each rotation. In this way the gauges are used to throw light on the problem of the fate of manurial materials in the soil, and on the problem of the rate of exhaustion of manures from the soil. As the crops grown on each gauge are also weighed and analysed, what is removed by them is known. Lysimeters used in this way provide direct evidence of what becomes of manurial materials applied to the soil, and show what proportion of them is washed away by drainage, what proportion is taken up by the crop, and what proportion is otherwise utilized in the soil.

At Craibstone the average annual rainfall measured alongside the lysimeters was 34·45 ins. for the ten years 1919-28. On the average, 19·35 ins. of drainage came through the unmanured drain gauge, and 18·88 and 18·19 ins. through the manured and the manured and limed gauges respectively. At Craibstone, therefore, on lysimeters which are cropped, more than half the rainfall percolates through the soil. As the manured lysimeters yield heavier crops than the one which is unmanured, they give rather less drainage as the heavier crops use up more water.

During the summer very little drainage comes through the lysimeters. In a normal year there are usually two or three months during the period June to September when there is no drainage. On the average, however, some drainage appears in each month, since in the case of protracted wet weather in summer drainage runs through. For the average of ten years less than one-tenth of an inch of drainage was recorded in the month of August. The average rainfall for the month was 2·38 ins. On the other hand, during the winter nearly as much water comes through as drainage as is recorded as rainfall. In the month of January, on the average of ten years, the drainage quite equals the rainfall, being in each case a little over 3 inches.

LYSIMETERS, OR DRAIN GAUGES (*Continued*)—

The drainage water contains in solution substances which are washed out of the soil, most of which are materials of value for the growth of crops. Nitrogen is washed away almost entirely in the form of nitrates, only traces of ammonia and other nitrogen compounds being found. Sulphates and chlorides are present in considerable quantities in drainage water. Carbonates are found in some drainage waters, but are rarely present in the drainage from the Craibstone lysimeters; but, on the other hand, large quantities of silicates are found in solution. Combined with the nitrates, sulphates, chlorides, and silicates are the bases lime, soda, magnesia, and potash. In Rothamsted drainage water, lime is the base present in by far the greatest quantity, but at Craibstone, in the case of the unmanured lysimeter, the soda found in the drainage is not much less in quantity than the lime. On the average of six years, 69·6 lbs. of lime per acre per annum, and 52·5 lbs. of soda were found in Craibstone drainage. A large amount of magnesia—the average for the same six years was 25·4 lbs.—is also washed out of the soil. On the other hand, the amount of potash found in the drainage is small. The average for six years was 10·5 lbs. per acre per annum from unmanured soil.

When the soil is manured, the amount of material in the drainage water is increased. This is true, generally speaking, both of the acid and of the basic substances in solution, but some remarkable exceptions are found to this rule in the case of the Craibstone lysimeters. When these experiments started it was expected that more nitrate would be washed from the manured than from the unmanured lysimeters, but this has not been found to be the case. Far less nitrate than was expected is dissolved out of the soil in all cases, and the amount does not vary very greatly in the case of the differently treated lysimeters. The average annual amount of nitrogen washed away from the unmanured lysimeter during a six-year rotation was 6·7 lbs. per acre, while in the case of the lysimeter which was manured with both dung and artificials, including ammonium sulphate, it was only 6·3 lbs. During the years when the lysimeters were under grass, and were, therefore, continually covered with vegetation, the amount of nitrate found in the drainage was specially low, and averaged only about 3·8 lbs. per acre per annum, calculated as nitrogen.

The practical conclusion to be drawn from these results is that when land is manured and cropped in the ordinary way there is little or no danger of loss of nitrogen from dung, or from soluble nitrogenous manures applied to the soil in spring. The danger of loss is especially small when the soil is covered with vegetation. The danger of the loss of the nitrogen of soluble manures in the case of heavy rainfall appears to have been much exaggerated.

Where ammonium sulphate and superphosphate are applied as manure, the sulphate in the drainage water is increased, but not the nitrogen or the phosphate. The phosphate is completely fixed in the soil, and is not washed away to any appreciable extent. When a potash manure is applied, the acid combined with the potash appears in the drainage, but the potash is not lost. The drainage from the

LYSIMETERS, OR DRAIN GAUGES (*Continued*)—
unmanured lysimeter at Craibstone contained on the average of six years 10·5 lbs. of potash per acre per annum; the lysimeter which received dung and also a moderate dressing of muriate of potash yielded on the average only 10 lbs.

Manuring with dung and artificials leads to an increase of the bases lime, magnesia, and soda in the drainage, so that manuring increases the loss of basic material from the soil, and increases the necessity for the use of lime to maintain the supply of available base. The lysimeter which was limed, as well as manured, yielded, as might be expected, much more lime in the drainage than the others. On the average, the lime was washed away from the manured lysimeter at the rate of 78·5 lbs. per acre per annum, and from the manured and limed lysimeter at the rate of 111·4 lbs. per acre per annum.

The Craibstone lysimeters are the only ones in the country which measure what is washed away from the soil under ordinary farming conditions, and many years of experiment will be required in order to supply evidence which is thoroughly reliable. The results, so far as they go, however, show that the chief loss of the soil through drainage is in basic materials like lime, magnesia, soda and, to a much smaller extent, potash; that there is no appreciable loss of phosphoric acid, and that the loss of nitrogen is very small.

J. H.

END OF VOL. I.

Printed in Great Britain for Baillière, Tindall and Cox, by Billing and Sons Ltd., Guildford and Esher